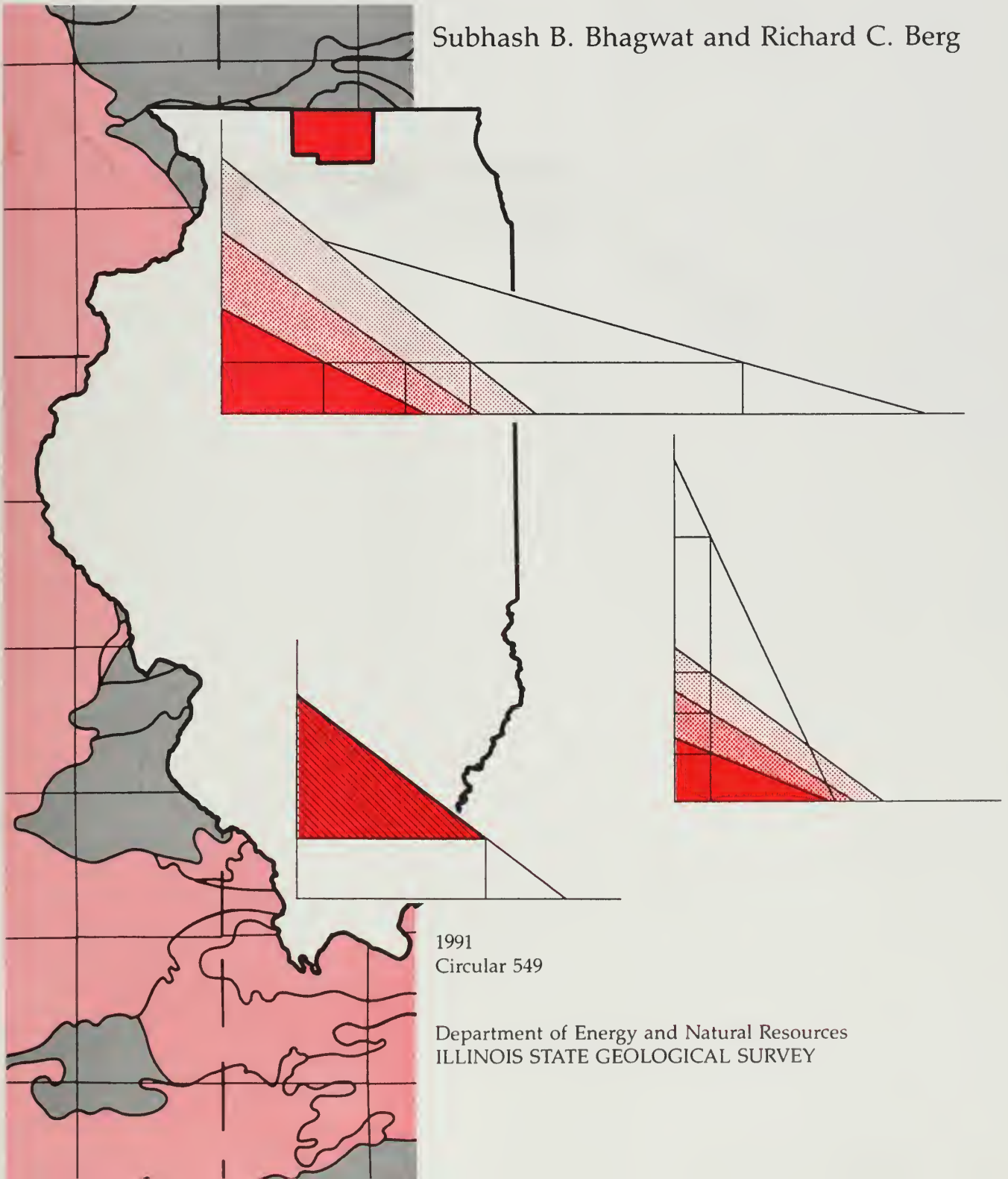


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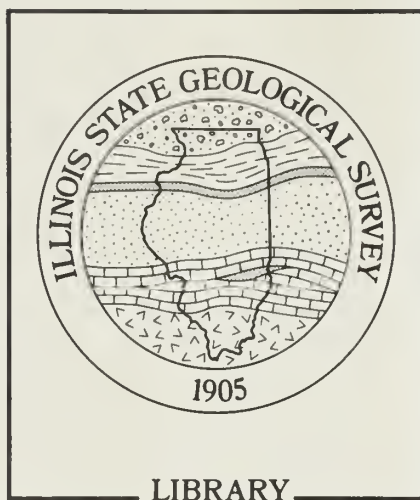
Benefits and Costs of Geologic Mapping Programs in Illinois: Case Study of Boone and Winnebago Counties and Its Statewide Applicability

Subhash B. Bhagwat and Richard C. Berg

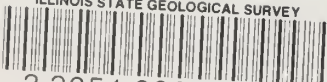


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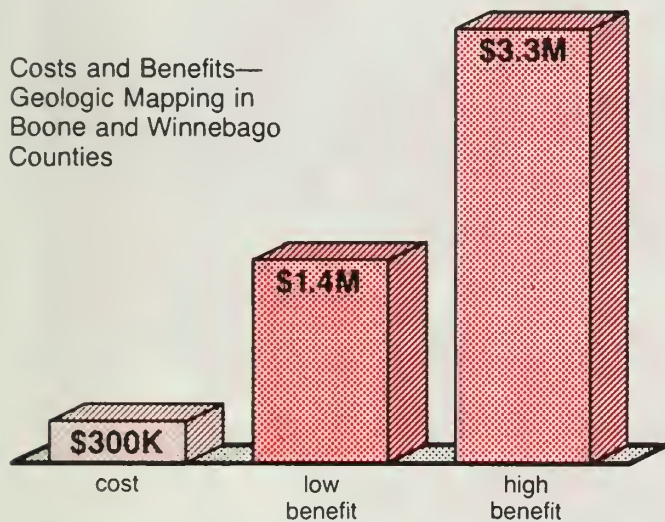
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GEOLOGIC MAPPING PAYS FOR ITSELF—MANY TIMES OVER

The benefits of geologic mapping outweigh the costs.

What geologists have long believed to be true is now documented for Illinois in this case study conducted by the Illinois State Geological Survey (ISGS). Well-known economic principles were applied to benefit and cost data for geologic mapping in Boone and Winnebago Counties. The results should be of interest to private industry, as well as county, state, and federal officials.

Using known costs and conservative estimates of benefits derived from mapping, ISGS mineral economist Subhash Bhagwat and geologist Richard Berg calculated a range of benefit/cost (B/C) ratios for the mapping of Boone and Winnebago Counties. They then projected B/C values for the entire State of Illinois. Their results are clear: the knowledge gained from geologic mapping will pay for itself—many times over.



In the early 1980s, ISGS geologists investigated and mapped the geology, hydrogeology, and mineral resources of Boone and Winnebago Counties. The results, reported in ISGS Circular 531, *Geology for Planning in Boone and Winnebago Counties*, were used to support public and private land-use planning and resource development.

Among the most useful products of the study were comprehensive maps describing and classifying the geologic materials of the two counties (for example, see figure on following page). Using the detailed information supplied on this and similar maps, county officials, engineers, and land owners, can make informed decisions

on such key issues as the siting of waste disposal facilities, and industrial, residential, and commercial areas. The maps are also used to locate sources of groundwater, construction aggregate, and other mineral resources.

Because the mapping of Boone and Winnebago Counties was so comprehensive and the information has been in use for almost 10 years, this area was ideal for studying the benefits and costs of geologic mapping. The cost elements of the B/C ratios were relatively simple to calculate because the costs of the mapping were well documented.

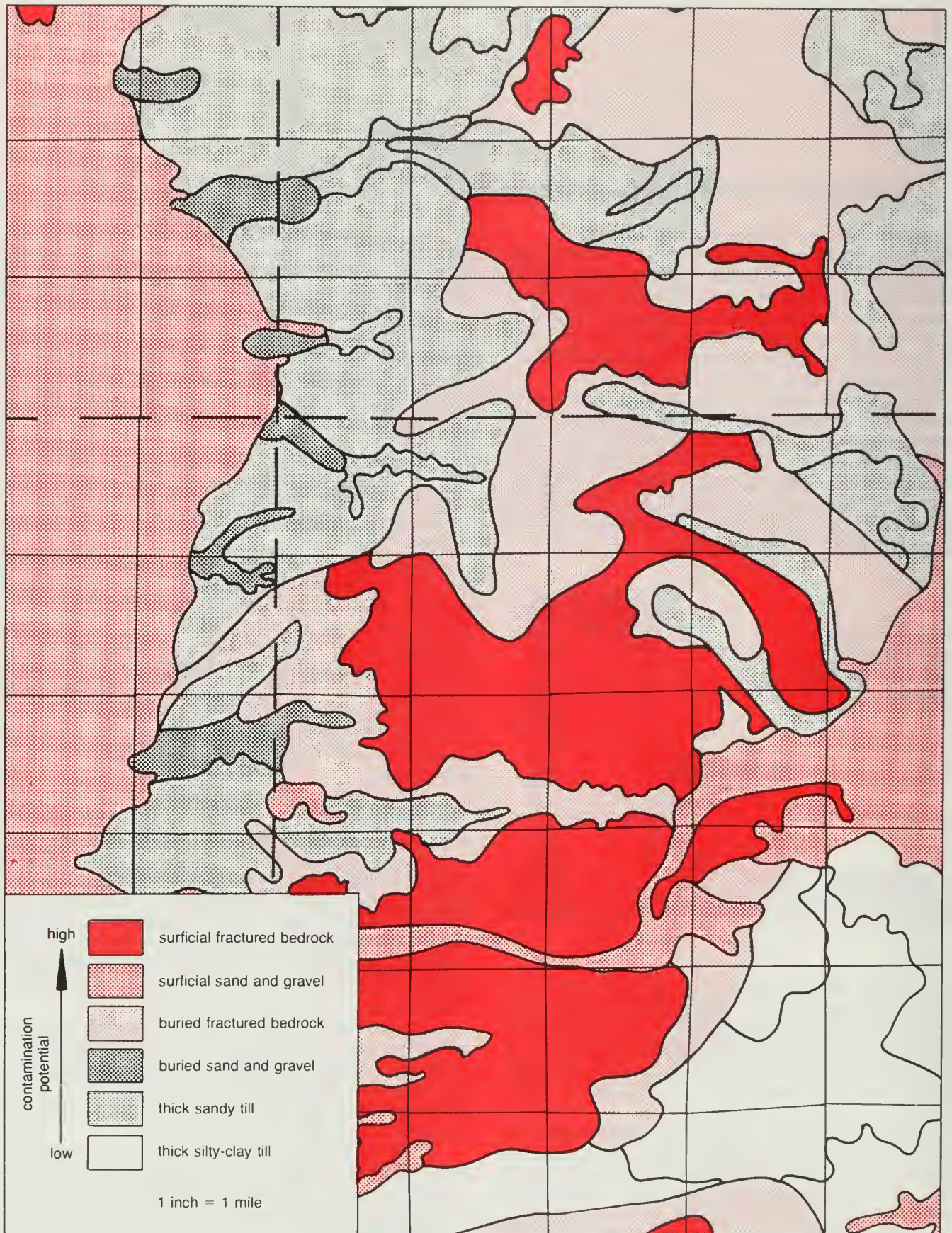
The benefits of geologic mapping were not so easily calculated. Better land-use planning and enhanced education, for example, are not quantifiable. Detailed information on mineral resource development is not readily available.

Rather than work with limited and uncertain data, the authors chose to be as conservative as possible and focused on only one item: costs that could have been avoided for investigating and cleaning up existing contaminated waste disposal and industrial sites in Boone and Winnebago Counties. If sufficient geologic information had been available at the time siting decisions were made, all or part of the clean-up costs could have been avoided. The money not spent ("avoidable" costs) on these sites thus would represent a savings (benefit) in this model.

Several sources of information were used to construct an estimate of these avoidable costs. One was actual cost information—money already spent on clean-up—from the Illinois Environmental Protection Agency (IEPA). For proposed clean-up sites without actual cost data, cost estimates from the IEPA and others were used, but each estimate was reduced in relation to its uncertainty. For example, if an estimate was $\$1000 \pm 30\%$, the lowest value of \$700 was used. The actual and estimated avoidable costs were then added to give the total calculated benefit.

Because not all of the geologic information collected would be used immediately, the authors introduced a time lag of 10 years before implementation of any benefits. They also assumed that as little as 1/10 of the total calculated benefits would be realized because not all of the information would be used.

Even with these conservative methods for generating and using estimates, they discovered that the benefits of mapping in Boone and Winnebago Counties were 5 to 11 times greater than the costs in the most conservative scenario (benefits reduced to 1/10). It is more



The classification of geologic materials for land burial of wastes in Boone and Winnebago Counties, Illinois (1984). Areas marked in red are poorly suited for siting waste-disposal facilities. White indicates those areas best suited for land burial of wastes. Such maps are used to screen potential sites of landfills and other waste-disposal facilities.

likely, however, that benefits would only need to be reduced to 1/4. In this case, benefits were up to 27 times greater than costs. In statewide projections, they found benefits were as much as 3 times greater than costs in this most likely scenario.

As impressive as they are, these B/C ratios reflect only the avoidable clean-up costs. Detailed geologic maps are used for much more. In Boone and Winnebago Counties, they are used in locating and extracting mineral resources, including stone for construction and groundwater. Teachers use these maps for science and environmental courses. Developers and zoning officials refer to the maps in screening areas for potential residential and commercial use. Consultants and local

officials refer to the maps to evaluate the contamination potential of aquifers from waste disposal and other land-use activities. Even in these few examples, it can be seen that a more complete accounting of the benefits of mapping would lead to even higher B/C ratios.

This study is one of the first that clearly demonstrates that geologic mapping is not merely a scientific "ivory-tower" exercise. It is more like preventative medicine. Money spent on mapping today will prevent expensive errors in siting waste disposal facilities, and industrial, commercial, and residential areas. In a time of tight budgets, the costs of geologic mapping may seem high. As this study clearly indicates, the costs of *not* mapping are much higher.



Morris W. Leighton, Chief
Illinois State Geological Survey



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ABSTRACT

In 1989, the Illinois State Geological Survey was required by Illinois Senate Resolution (ISR) 881 (superseded by ISR 98 in 1991) to document the benefits and costs of geologic mapping programs. Boone and Winnebago Counties were selected for the benefit-cost study.

The cost of geologic mapping in Boone and Winnebago Counties was recalculated in 1990 dollars to be about \$300,000. Two statewide mapping cost estimates were made, one extrapolated from Boone and Winnebago Counties (\$21 million) and the other on the basis of estimated differences between the Boone-Winnebago program and the proposed mapping program for the state of Illinois (\$55 million).

The basic economic premise in benefit assessment is that geologic mapping produces a "public good," in contrast to "private goods," such as consumer products. Because of the lack of documentation on possible benefits of geologic mapping programs, an indirect assessment of benefits had to be made based on this rationale: Future costs to the society could be avoided as a result of the knowledge gained through geologic mapping programs; these avoidable costs are equivalent to benefits, and thus attributable to the program.

Data collection on such future avoidable costs was based on 55 personal interviews in Boone and Winnebago Counties. The quantifiable data were separated

from the nonquantifiable and then classified into four levels of decreasing confidence. Quantifiable benefit data were available only on part of the avoidable costs of cleaning up contaminated sites from waste disposal and industrial activities. Geologic mapping will not eliminate all such costs but can help reduce them significantly. This study considered three scenarios in which the benefits (i.e., avoidable costs) were reduced by 50, 75, and 90 percent to account for the effectiveness of legislation in place.

The reduced benefits were grouped into four cumulative categories. To account for delays in proper utilization of knowledge gained from the mapping programs, a 10-year delay in benefit realization was assumed. The benefits were then discounted to convert the dollar amounts to the 1990 basis.

In the most comprehensive benefit category, 4, the benefit-cost ratio for Boone and Winnebago Counties ranged between 5 and 55. The statewide projection of benefits was based on county areas and an aquifer contamination potential score for each county. The score depends on the depth of aquifers and the number of sources of potential contamination. The statewide benefit-cost ratio in benefit category 4 ranged from 1.2 to 14 at the \$21 million mapping cost level and from 0.5 to 5.4 at the \$55 million mapping cost level.

EXECUTIVE SUMMARY

In 1989, the Illinois State Geological Survey (ISGS) was required by Illinois Senate Resolution (ISR) 881 to document the benefits and costs of geologic mapping programs. ISR 881 was superseded by ISR 98, adopted in March 1991. Because the most detailed geologic mapping had been done in Boone and Winnebago Counties, the ISGS used the two counties as a case study.

The cost of geologic mapping conducted in 1980 in Boone and Winnebago Counties was recalculated in 1990 dollars by using 1990 salary levels and drilling costs (provided by drillers). The cost of geologic mapping in other parts of Illinois will depend on the complexity of geologic conditions, amount of additional data required, methods of data processing and map production, and the degree of detail required. Two cost scenarios were considered: one based on projection of the Boone-Winnebago mapping, and the other on a cost estimated by ISGS geologists for a statewide mapping program.

Benefits of geologic mapping were difficult to quantify; no past applied experience existed and benefits occur for decades after geologic maps are used in decision making. The basic economic premise in benefits assessment was that geologic mapping produces a "public good" in contrast to "private goods," such as consumer products. The implication of this difference is that the market demand curve for geologic mapping programs is a result of the vertical summation of individual demand curves compared with a horizontal summation of individual demand curves for a private good. Because so little documentation is available, an indirect assessment of benefits had to be made. The assessment was based on the rationale that a future cost that could be avoided because of knowledge gained through a geologic mapping program is equivalent to benefits and attributable to the program.

Data collection on such future avoidable costs was based on 55 personal interviews with actual or potential users of geologic information in Boone and Winnebago Counties. Some information was quantifiable in dollars, but much more was of a qualitative nature. The results of this study must be used only in conjunction with appropriate weighing of qualitative benefit data.

Quantifiable benefit data were available only in the form of the potentially avoidable costs of cleaning up contaminated sites from waste disposal and industrial activities. Although it cannot be assumed that geological mapping will result in eliminating all costs at all future waste disposal and industrial sites, costs could be significantly reduced if geologic maps are used. There are at least a dozen other uses of geologic information and many potential sources of benefits. All factors must be given appropriate weight in decision making in regard to geologic mapping programs.

The results of this study are based on a single type of benefit (i.e., avoidable costs), reduced 50, 75, and 90 percent to take into consideration the future effectiveness of environmental regulations in place:

Scenario 1 Benefits were reduced 50 percent on the assumption that no dramatic change from past practices will occur in siting facilities and disposing of wastes. Regulations currently require consideration of geology in siting of waste disposal facilities but do not include siting of industrial facilities.

Scenario 2 Benefits were reduced 75 percent to account for progress in regulating and designing safer waste disposal facilities that will help prevent contamination problems at many sites.

Scenario 3 Benefits were reduced 90 percent on the assumption that regulatory changes in the near future and the already existing regulations on siting industrial and waste disposal facilities will be highly effective and the design of engineered structures highly successful.

The quantifiable benefits were analyzed for the appropriate level of confidence to be vested in the data. Four categories of benefits were made with decreasing levels of confidence:

Level 1 Highest confidence, ± 0 percent variability, was placed on expenses incurred by the Illinois Environmental Protection Agency (IEPA) for site investigation and cleanup work as of June 30, 1990.

Level 2 A confidence level of ± 10 percent was assigned to expenses already incurred but not as well documented as the IEPA expenses.

Level 3 Estimates of cleanup costs available from feasibility studies were assigned a ± 30 percent confidence, as is commonly done for any feasibility report.

Level 4 Other estimates by experienced managers were classified into the ± 50 percent confidence category.

The confidence levels simply indicate the dollar ranges within which benefits are expected to fluctuate; they do not reflect doubt that such benefits will accrue.

Because most benefits will accrue in the future, and their occurrence will be dependent upon appropriate and timely use of geologic information, a conservative approach was taken to benefits estimates. No precedent was available to translate this conservative approach into a mathematical formula. Therefore, benefits were assumed to be delayed by 10 years due to technical, educational, organizational, and political difficulties in making practical use of the geologic knowledge gained from the mapping program. The delayed benefits for avoidable costs were discounted at a 10-percent annual rate in order to convert the dollar amounts to the 1990 basis. Adjusted benefits were then used to determine the benefit to cost (B/C) ratio in four benefit categories. Category 1 benefits are the same as level 1 benefits. Subsequent benefits categories include cumulative benefits from the four levels of benefits described above. Thus, category 2 includes benefits from levels 1 and 2, category 3 includes benefits from levels 1, 2, and 3, and category 4 includes benefits from all four levels of confidence.

B/C ratios for Boone and Winnebago Counties

	Category 1	Category 4
Scenario 1	1.65	23.5 to 54.5
Scenario 2	0.83	11.7 to 27.2
Scenario 3	0.33	4.7 to 10.9

The statewide projection was based on county areas and an aquifer contamination potential score determined for each county using the location of aquifers and the number of sources of potential contamination. With this method, the projected total cost of mapping for Illinois was about \$21 million. In the table below, this cost of mapping is the lower cost.

An alternative statewide calculation of B/C ratios was made from a higher assessment of cost of geologic mapping by ISGS geologists. Because of differences in geology and the amount of additional work needed, the cost of statewide mapping would be \$55 million instead of \$21 million, as projected from the program on Boone and Winnebago Counties.

Projected statewide B/C ratios

	Category 1		Category 4	
	lower cost	higher cost	lower cost	higher cost
Scenario 1	0.4	0.2	6 to 14	2.3 to 5.4
Scenario 2	0.2	0.1	3 to 7	1.2 to 2.7
Scenario 3	0.1	—	1.2 to 2.8	0.5 to 1.1

We believe that a realistic reference point for interpreting the results of this study is the range of B/C ratios in category 4. With this reference point, the results can be summarized as in the table on the following page. The B/C ratios shown in this table are for avoidable costs related only to soil and groundwater contamination. The ratios will increase as the numerous other benefits that could not be considered in this study are included.

	Cost (1990, in millions)	Scenario	B/C ratio	Total benefits (1990, in millions)
Boone and Winnebago Counties	\$ 0.3	1	23.5 to 54.5	\$ 7.0 to 16.3
		2	11.7 to 27.2	3.5 to 8.1
		3	4.7 to 10.9	1.4 to 3.3
Statewide projection from Boone and Winnebago Counties	21.0	1	6.0 to 14.0	127.0 to 295.0
		2	3.0 to 7.0	63.0 to 147.0
		3	1.2 to 2.8	25.0 to 59.0
Alternative estimate based on ISGS assessment of costs	\$55.0	1	2.3 to 5.4	127.0 to 295.0
		2	1.2 to 2.7	63.0 to 147.0
		3	0.5 to 1.1	\$ 25.0 to 59.0

BACKGROUND

Geologic information is widely known to be used in mineral exploration and extraction. Accurate, detailed geologic information has been effectively used to mitigate problems of mineral availability, but its use in investigating water resource availability and contamination of the earth due to human activity is not so widespread.

Geologic maps are a prerequisite in searching for minerals. Although many minerals are imported into the United States, many others are being produced domestically in increasing amounts. Almost 90 percent (by value) of the nonfuel mineral raw material needs of the United States are met by domestic production, and despite an oil-import bill exceeding \$50 billion in 1989, the United States continues to produce more than 50 percent of its oil needs, all of its coal needs, and most of its gas needs. Despite centuries of exploration and mining, the potential for new mineral discoveries through advanced mapping techniques remains attractive.

Water is an extractable mineral commodity of vital importance for industrial and economic growth. The potential for contaminating groundwater resources has become a nationwide concern for health and safety reasons. Contamination can result from use of agricultural chemicals, septic systems, accidental spilling of chemicals or oil, leakage of underground storage tanks, spreading of sewage sludge, leachates from landfills or coal gas waste sites, and disposal of municipal, hazardous, or radioactive waste. Potential health risks can arise when chemical or biological agents from the waste source enter the groundwater system and are then extracted from public or private wells. Mapping areas as to their risk for contamination can help alleviate threats to groundwater.

More land is being subtracted from agricultural, forest, and mining uses by urban growth than by any other activity. Urban growth exacerbates waste generation and pollution and renders earth resources inaccessible. Geologic mapping helps in planning urban development in a manner that prevents pollution and retains access to earth resources.

Unfortunately, public and private decision-makers are not adequately using geologic knowledge for plan-

ning, partly because of a lack of awareness and partly because such detailed geologic knowledge does not exist. The more policymakers use geology for planning, the more they will find that it makes economic sense to do so.

For most of Illinois, detailed geologic mapping does not exist. To remedy this situation, the Illinois Senate Resolution 881, passed on June 13, 1989, asks the Illinois State Geological Survey (ISGS) to prepare a statewide mapping initiative. ISR 881 also requires that the ISGS provide a cost-benefit study of the recommended geologic programs. Besides ISR 881, The Illinois Groundwater Protection Act (IGPA, P.A. 85-863) mandates that the ISGS conduct a geologic mapping program. Section 7 (a) (2) states that the Department of Energy and Natural Resources (ENR) shall conduct assessments to enhance the state's database concerning groundwater resources, mapping of aquifers, identification of appropriate recharge areas, and evaluation of baseline groundwater quality. The ISGS (sections 14.1, 14.2, 14.3) must also assist the Illinois Environmental Protection Agency (IEPA) in acquiring geologic data that (1) identify aquifers for determining wellhead setbacks, (2) provide hydrogeologic data to determine expansion of setback zones, and (3) identify hydrogeologic characteristics of materials and the depth to the uppermost aquifer for the assessment of groundwater protection needs, and for establishment of groundwater protection planning regions and regulated recharge areas (sections 17.1, 17.2, 17.3, 17.4).

In 1980, geologic mapping suitable for planning purposes was conducted in Boone and Winnebago Counties. The two-county area was mapped extensively and could serve as a model for future geologic mapping programs.

This study documents the potential and actual uses of the Boone-Winnebago geologic study and its benefits. As in any publicly funded program, benefits of geologic mapping can be only partly quantified in terms of dollars. This study compares the quantifiable and non-quantifiable benefits of geologic mapping in Boone and Winnebago Counties with the costs of mapping, and the results are extrapolated to the entire state of Illinois.

LITERATURE REVIEW OF BENEFIT-COST STUDIES IN GEOSCIENCES

Benefit-cost studies have been prepared for public expenditure projects formally and informally for many decades, but their application to geosciences is relatively recent (McGrain 1966, 1967). Early applications of B/C analysis in geosciences were largely anecdotal. For example, a study by McGrain (1979) relates the growth in Kentucky coal production to a simultaneous growth in the number of published geologic maps. The study also describes other uses of maps, including specific examples by industry. However, a satisfactory causal relationship is not sufficiently well established to enable quantification of benefits. Literature on B/C studies in geosciences is limited and consists mostly of applications to projects or programs with single objectives. For example, a University of Maine study (Epstein and Duchesneau 1984) applies the B/C analysis to a geodetic reference system.

The 1980s saw the first meaningful attempts to develop methodologies for benefits versus cost evaluations of projects or programs in geosciences. These efforts benefitted from theoretical and practical work in the area of agricultural economics, especially in conjunction with irrigation projects (Willet et al. 1975, Torell et al. 1990). Clapp et al. (1985) attempted to develop an approach to evaluating land information systems on the basis of operational efficiency, operational effectiveness, program effectiveness, and contribution to societal well-being. The first two criteria concern effective data collection and user access to the data. The third criterion refers to the degree of use of the data by those who ought to be using them, and the fourth criterion evaluates what the program has contributed to the well-being of the whole society. The approach by Clapp et al. (1985) makes sense, but it is hard to apply if benefits are to be quantified in dollars. However, quantification in terms of dollars should not be the only (and sometimes is not even the best) criterion for program evaluations because intangible benefits may heavily outweigh the tangible ones. Applying the approach of Clapp et al. (1985) to the Illinois Geographic Information System (GIS), Treworgy et al. (1988) showed that this evaluation approach was useful in assessing the costs and benefits of developing and managing a geologic database.

Literature on B/C studies for specific geologic applications is even more scarce than in the geosciences in general. Applications have generally been limited to single-issue case studies. Bernknopf et al. (1988) developed and applied a B/C analysis approach to landslide hazards in Ohio. The approach is based on a technical assessment of factors causing landslides, their probability of occurrence on a site-by-site basis, the damage they may cause, and estimates of costs involved in mea-

sures necessary to prevent the landslides. Another related study by Bernknopf et al. (1990) deals with the benefits and costs of sending notices of volcanic and earthquake hazards to residents of certain areas of California. The benefits of such notices come from avoided physical and economic harm to the residents, and the cost may be in terms of lower housing prices, reduced tourism and other investments, and unnecessary fears.

Knight (1989) describes, with a hypothetical case study, a method for evaluating the benefits and costs of different levels of geophysical (seismic) surveys in oil exploration. As seismic surveys become more sophisticated, their cost also increases. On the other hand, a benefit is accrued as a result of more sophisticated seismic surveys because the probability of unproductive oil well drilling is lowered.

Geologic information has wide applications for resource development, waste disposal issues, groundwater protection problems, and public health in general. The United States Geological Survey (USGS) has attempted to develop an approach to apply the B/C analysis to include all possible uses of topographic (primary base) maps (USGS 1987, 1988). The USGS study deals with the issue of revision and printing of maps and not with the mapping program itself. About 57,000 topographic quadrangle maps at 1:24,000 scale cover the entire United States. It would take a half century and billions of dollars to replicate all the maps. The choice of quadrangles to be prioritized for revision and the number to be revised each year should depend upon benefits to be expected from the map revisions.

The USGS study relies on nationwide interviews of federal, state, and local government agencies and private businesses to make a list of possible uses of topographic maps and to determine the alternatives that the interviewees would choose if the USGS did not revise the maps. Answers to questions regarding frequency of needed map revisions serve to prioritize revisions of topographic maps by geographic areas. The survey of potential users indicated at least 200 different uses of maps. Because of the multiplicity of uses of topographic maps, the USGS study of benefits and costs concentrates on five states and relies on answers to questionnaires given by the users. Estimates of benefits were made on the basis of qualitative answers from users given a decision tree provided by the USGS. The decision tree elicited answers from users on steps they would take to acquire topographic knowledge if maps were not revised. Each stage in the decision tree was assigned a cost by USGS researchers, and this was the means by which qualitative answers were converted into dollar amounts.

SCOPE OF THE PRESENT STUDY

Geologic Mapping in Boone and Winnebago Counties

In December 1979, the ISGS was contracted by the boards of Winnebago and Boone Counties to conduct a geologic mapping program over a 2-year period. The objectives were to (1) map surficial deposits (glacial drift), produce a map showing the sequence of these materials to a depth of 20 feet, and define the characteristics of glacial drift deposits to bedrock; (2) prepare a series of interpretive maps showing contamination potential of the glacial drift materials, areas of probable recharge, suitability of these geologic materials for construction, and areas of mineral and groundwater resources; and (3) prepare a report on the geology of the counties.

In late 1981, a contract report was provided to the counties, satisfying the objectives of the contract. This report was subsequently published in 1984 as ISGS Circular 531, *Geology for Planning in Boone and Winnebago Counties* (Berg et al. 1984). The circular included more than the originally intended study. In addition to the map that shows the geology of surficial deposits within 20 feet of the surface (stack-unit map showing the sequence and areal distribution of units), the study provided the following basic geologic maps and cross sections.

Areal geology of the bedrock surface—delineates aquifers and nonaquifers.

Thickness and elevation of the top of the Ironton-Galesville Sandstone, and the Ancell Group (St. Peter Sandstone)—illustrates major regional aquifers.

Topography of the bedrock surface and drift thickness—indicates depth to potential bedrock aquifers and configuration of the bedrock terrain.

Numerous geologic cross sections through the counties—concentrate principally on the Rock and Troy deep bedrock valleys, which contain major drift aquifers.

Interpretive geologic maps were derived from the above maps and cross sections:

Classification of geologic materials for land burial of wastes—rates land areas and materials within 50 feet of the surface for high to low vulnerability to potential contamination from landfills and other waste disposal practices.

Classification of geologic materials for waste disposal by septic tank soil adsorption systems—rates land areas and materials within 20 feet of the surface for high to low vulnerability to potential contamination from septic systems, accidental surface spills, and other near-surface disposal activities. Poorly drained soils were also included on the map.

General construction conditions—evaluates the suitability of geologic materials for ease of excavation, ade-

quate bearing strengths to support structures, and drainage conditions.

Distribution of sand and gravel aquifers—delineates known groundwater resources in glacial drift deposits such as sand and gravel.

Sand, gravel, and peat resources—illustrates areas containing these resources and their thickness and depth beneath the surface.

Dolomite resources—illustrates dolomite exposed at the surface or buried at depths less than 20 feet.

Terranes—combines geologic materials and topography and can help determine groundwater gradient and permeability and therefore potential for natural recharge.

ISGS Circular 531 was widely distributed in Boone and Winnebago Counties, with copies provided to county boards, regional and municipal planning departments, health departments, highway departments, soil and water conservation districts, state regulatory agencies based in Rockford, well drillers, aggregate producers, geologic and engineering consultants, and other interested parties. The ISGS also conducted workshops, field trips, and training sessions on how to use this geologic report for resource-based, land-use planning and decision making. Since 1979, the ISGS has backed up this study by providing the citizens of Boone and Winnebago Counties clarification and assistance on the geology and hydrogeology of the area.

Assessment of Benefits and Costs of Geologic Mapping in Boone and Winnebago Counties

Boone and Winnebago are the only two counties in Illinois for which modern comprehensive large-scale lithostratigraphic and derivative (or interpretive) mapping has been conducted and published. Because of this intensive geologic mapping program, Boone and Winnebago Counties were selected for the B/C study.

This study identified actual and potential uses of the map products, listed the quantifiable and nonquantifiable benefits attributable to mapping, and compared the benefits with costs of mapping.

Comparison of Boone and Winnebago Counties with the Rest of Illinois

After the assessment of benefits and costs of geologic mapping in Boone and Winnebago Counties, the data were extrapolated to the entire state. This projection was based upon a comparison of hydrogeologic, geologic, and industrial data from all Illinois counties with Boone and Winnebago Counties.

TAXONOMY OF BENEFITS AND COSTS ASSOCIATED WITH GEOLOGIC MAPPING PROGRAMS

The costs and benefits of geologic mapping programs go beyond the immediate dollar amounts spent in conducting the mapping work or the amounts saved in terms of avoided costs. Society pays for and profits from publicly financed mapping programs in ways not amenable to immediate quantification. These social costs and benefits must be taken into account in decision-making.

Taxonomy of Benefits of Geologic Mapping

The benefits derived by society from geologic maps and their interpretations are largely in the form of future avoided costs. The principle of avoided cost may be less obvious for mineral extraction industries that generate wealth and thus do not merely avoid future costs. In the absence of basic geologic maps, however, each competitor in the extraction industries will generate proprietary geologic information not available to others. This acquisition of geologic information represents part of the costs that could be avoided if publicly funded geologic mapping were undertaken. The ultimate gains are made by the society as a whole in terms of opportunities for investing the savings into projects and ventures of greater utility. These benefits are considerable:

- Potential direct savings in terms of avoided costs for cleanup of a significant number but not all waste disposal sites and industrial contamination sites. These are immediate savings that could be invested profitably in other industrial ventures creating new wealth or in other worthwhile public projects such as health and education.
- Indirect benefits from avoided contamination of land and water are gained in terms of better health and longevity, which in turn translate into productivity gains by the society as a whole.
- Maps used in educating students and adults, politicians, and planners can result in increased awareness of the consequences of human activity and in a better educated generation. These benefits are intuitively clear but impossible to quantify.
- Cost savings by mineral producers, water supply companies, and drilling contractors translate into greater national and international competitiveness of the domestic industry, new jobs, and security.
- Geologic maps with information on agronomic soil characteristics, slopes, and watersheds serve the agricultural community in various ways. Soil conservation is the most important long-term benefit because human existence depends on soil to grow food. Other benefits arise out of proper application of fertilizers and pesticides not only to optimize the economics of agricultural production but also to protect the surface and groundwater from contamination.
- Geologic maps supply useful information for urban development and infrastructure planning. The knowledge of soil and rock strength, subsurface geology, and hydrology can reduce potential health and safety haz-

ards as well as the cost of creating and maintaining the infrastructure.

- Geologic maps on county scales cannot substitute for site-specific detailed studies and therefore will not avoid those costs. However, maps can help eliminate undesirable sites, reduce site selection costs, and improve the confidence level of decisions.

Many of the above benefits are not measurable. In Boone and Winnebago Counties, maps have been available and accessible to anyone interested in them. It is hoped that a documentation of benefits and costs will help improve decision-making. If political and business decisions must be made regarding land use, those decisions should be based on a solid geologic foundation.

Taxonomy of Social Costs of Geologic Mapping

Money spent on conducting geologic mapping constitutes only one type of cost—the direct monetary cost measurable by available accounting methods. Several other types of costs that must be taken into account do not lend themselves easily to conventional quantification. These costs, borne by society, are discussed below.

- Money spent on geologic mapping can be spent on other, possibly more desirable, programs involving human welfare.
- Preparing geologic studies through mapping programs may have to be followed by technology transfer or regulatory mechanisms that will ensure their use in the planning process. The cost of establishing such mechanisms must be accounted for as a social cost.
- Geologic maps may be used to determine ideal locations for new subdivisions or waste disposal facilities. Maps may also be used to ensure that natural resources such as minerals or water are not rendered unextractable. (This can result in long transportation distances and higher costs to the society.) Another social cost may arise if the geologically ideal site for waste disposal or mining is located in an aesthetic area that may be destroyed. Moreover, the owner of the geologically ideal site or people living in the vicinity may object to locating waste disposal or mineral extraction facilities there because it may lead to loss of property values or deterioration of the neighborhood. What monetary compensation will they accept for the devaluation of their land or neighborhood? The required compensation represents a social cost related to geologic mapping.
- Businesses may choose not to locate in a community, county, state, or country if they perceive the application of geologic criteria for prevention of environmental contamination to be a deterrent to investment. The loss of employment and potential tax revenues represents a social cost. The more widespread the use of geologic maps, however, the more these social costs become irrelevant because businesses would have fewer choices of locations free of these social costs.

ECONOMIC RATIONALE IN BENEFITS ASSESSMENT

Geologic mapping programs generate information or knowledge that is used in many ways. The products of the program are not always tangible. The maps produced are tangible; however, the most important aspect is the composite knowledge represented on the maps. Because of the unusual nature of the "product" of geologic mapping programs, the economic rationale in the assessment of their benefits is discussed in this section.

Private Goods Versus Public Goods

Most goods, once they have been purchased, are inaccessible to others. For example, one cannot increase consumption of cars or candy without reducing their availability to others. Such goods are called private goods. Other goods benefit everyone regardless of whether everyone wants them. Public goods, as they are called, remain available to others even after one or more individuals have "consumed" them. Examples of public goods may be clean air, national defense, or public health care.

An increase in the production of a private good by one unit serves only the buyer of that unit. By contrast if more clean air is "produced," everyone benefits. Some goods such as air pollution or water pollution are undesirable byproducts of other economic activities. Production of undesirable goods (or "bads") can often be prevented at a cost, borne ultimately by the consumer. For example, air pollution can be prevented by using so-called "scrubbers" in electricity-generating plants. The cost of scrubbers is paid by those who consume electricity. Like "public bads," some public goods are produced as byproducts of other primary economic activities. For example, a homeowner who spends money to professionally landscape the yard may help increase property values of neighboring houses. Such unintended effects are also called "externalities." Externalities can be both negative (air pollution) and positive (landscaping) and can occur in conjunction with the production of private and public goods.

The distinction between a private good and a public good also depends on the spatial context of the problem. For example, an electricity-generating plant in central Illinois may produce clean air by using a scrubber. The main beneficiaries of this public good are residents of central Illinois and to a lesser extent, because of prevailing winds, those living to the east and northeast of Illinois. However, residents of the western United States may not benefit from the public good produced by this central Illinois plant, but may be able to do so if they pay the price of moving to the east. Since not everyone automatically benefits from the clean air "produced" by the scrubber, does this disqualify clean air as a public good? This might appear to be the case at first. However, the health and other benefits accrued to residents of the eastern United States benefit all Americans as taxpayers who pay for health research and treatment regardless of their place of residence.

Geologic Maps as Public Goods

Geologic mapping programs produce maps as tangible products that impart knowledge. In this sense, mapping programs generate products quite different from most other products. Geologic maps qualify for the designation of public good for reasons similar to those discussed above. Mapping, once carried out, benefits everyone who resides or does business in the geographic area of the map, regardless of whether every person purchases a geologic map. Maps represent knowledge and as such, remain available to all for simultaneous or successive uses, even though a particular printed copy of the map is purchased and used by a limited number of people.

Although maps themselves have the characteristics of a private good, mapping programs that result in the production of maps have public good characteristics. Knowledge generated by mapping programs is accessible to all and is not diminished by consumption. And for reasons analogous to the case of clean air, geologic mapping creates benefits for people beyond the geographic area of mapping. The knowledge gained from geologic mapping, as discussed later in this report, contributes to the environmental as well as economic well-being of not only the residents of the mapped areas but the adjoining counties and the entire state. Some benefits transcend state boundaries, such as the benefits of savings derived from avoided federal expenditures for environmental cleanup or imports of raw materials, and even national security benefits if strategically critical minerals are discovered as a result of the mapping program.

The treatment of geologic mapping as a public good has important consequences in efforts to assess the benefits of mapping. One important consequence is the recognition that, unlike private goods, the decision-making process for geologic mapping is not limited to financial profitability alone. It involves a broader objective of social well-being with financial consequences that are unmeasurable or very difficult to measure in monetary terms.

Foundations in Economic Theory

How well-being is measured and how to determine whether society's well-being is enhanced through geologic mapping is subjective because well-being is subjective. Satisfaction or utility derived from consumption of goods cannot be measured, although goods will not be consumed unless the individual feels that they are worth purchasing. In this regard, consumers treat private goods differently from public goods such as geologic mapping programs. Production will continue for a private good such as an automobile, so long as at least one individual is willing to buy that unit at the prevailing market price, i.e., so long as at least one individual believes that buying that unit will enhance his or her well-being. The concept of consumer surplus is used to understand consumer well-being, as summarized below.

The consumer of a private good places different values on successive units of the good consumed. The first unit of consumption is generally valued more than the successive units. This value is expressed in the consumer's willingness to pay the highest price for the first unit and the lowest price for the last unit consumed. The market price, however, is determined by the marginal cost of production or the cost of producing an additional unit demanded. As a result the consumer gets a higher value from the earlier units of the good than the market price he/she pays per unit. In figure 1A, the consumer demands a quantity Q_1 , when the price per unit is P . However, this consumer is willing to pay more for all units preceding the Q_1 th unit (i.e., he/she gets a greater utility from consumption of Q_1 units of the private good than the amount $(P \times Q_1)$ paid by him/her indicates). This excess utility, represented in figure 1A by the area of the shaded triangle D_1Pa , is called consumer surplus, which consumers strive to maximize regardless of whether a private or a public good is consumed.

In figure 1A, D_1D^1 represents the demand per time unit (e.g., year, month) at different price levels by this particular individual consumer. When there are many consumers of a private good, their individual demand schedules D_2D^2 , D_3D^3 , and so forth can be horizontally summed to represent the market demand schedule D_3D^* (fig. 1B) and the area under the demand schedule D_3D^* and above the price line P represents the total consumer surplus of all consumers in the market.

Unlike private goods, the market demand for a public good such as geologic mapping programs cannot be determined by horizontal summation of individual demands because when an additional unit of a public good is made available, it benefits everyone at the same time. Therefore, the value of a quantity of public good to the society is the sum of values placed on that quantity of the public good by all the consumers. More elaborate theoretical treatment of the topic can be obtained from a number of textbooks and practical guides to B/C analysis (Glahe and Lee 1981, Sugden and Williams 1978, Anderson and Settle 1977).

The vertical summation of individual demands for a public good (as against the horizontal summation for a private good) is depicted in figure 1C. If there are three consumers of a public good with demand curves D_1D^1 , D_2D^2 , and D_3D^3 , the values placed by these consumers per unit of a public good provided in quantity Q_1 will be P_1 , P_2 , and P_3 , respectively. The cumulative value per unit to the society is $P^* = P_1 + P_2 + P_3$, as every unit of the public good is available to all three consumers at the same time.

Because geologic mapping programs are a public good, their production depends upon whether the marginal cost of production is justified by the value the society cumulatively assigns that unit. This criterion of production decision for a public good often leads to the phenomenon—everyone wants it, but no one will pay for it (Travis and Doty 1990). Suppose in figure 1C that

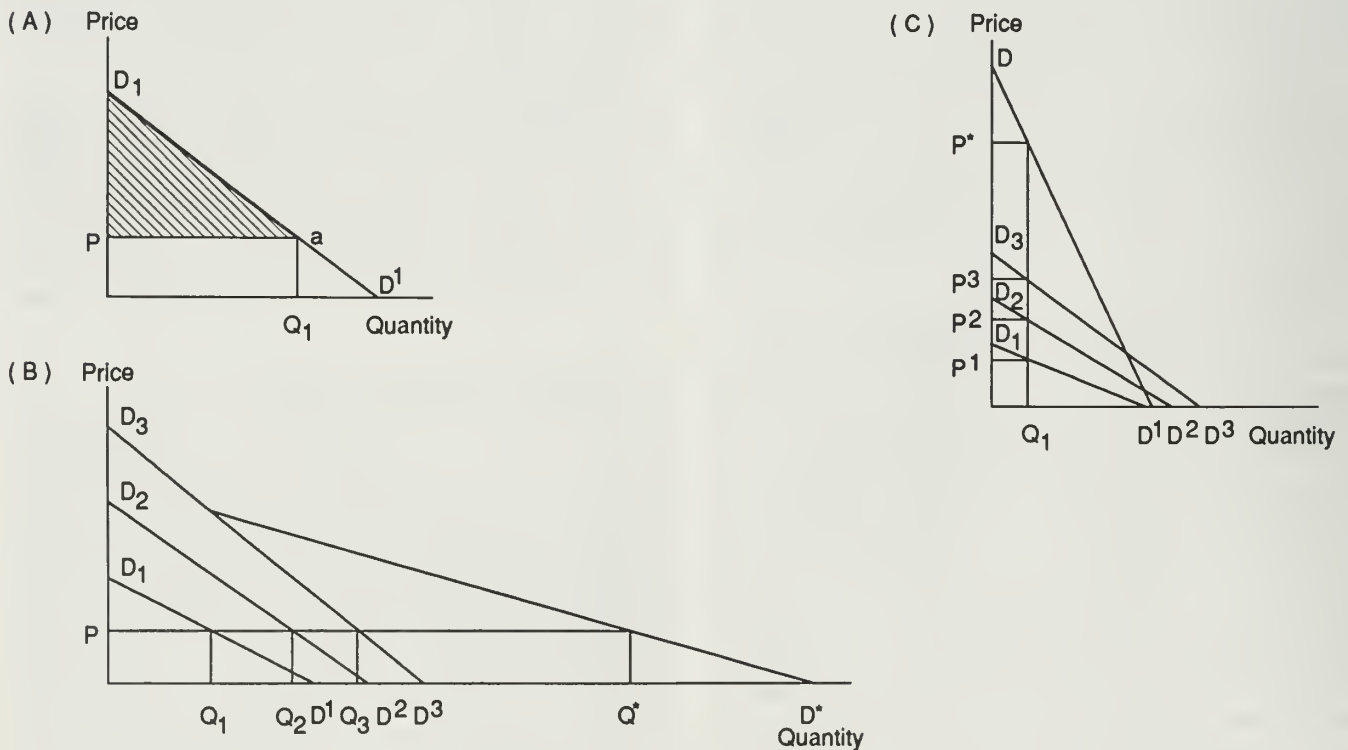


Figure 1 Market demands for public and private goods: (A) consumer surplus, (B) demand for a private good, and (C) demand for a public good.

P^* does equal the marginal cost. In that case it would be necessary to produce Q_1 units of the public good and price it at P^* per unit. Unfortunately, none of the three consumers in figure 1C will buy the public good because their valuations (P_1 , P_2 , and P_3) of the good are lower than P^* . Because in reality there is generally at least one buyer in the society for the public good at a price P^* commensurate with the marginal cost, the situation often leads to the free-rider syndrome. For example, in figure 1C, if a fourth consumer came forward and bought the public good at its designated price P^* , all other consumers would get the public good at little or no cost.

For geologic mapping, a similar scenario can be expected in the decision-making process because potential beneficiaries of the mapping programs may not want to pay for the program knowing that access to the results will be available once mapping is completed. Users of geologic maps may also benefit from the product's use to different degrees and may therefore willingly pay varying amounts (or nothing at all) to get the mapping done. Some users might even deliberately understate the value of the product in order to reduce their share of payment for the mapping program. Quantification of the actual utility of the mapping program to the user remains elusive. Demand curves for individual map users are not easily established. The best possible approach to solving the difficulty is to quantify the demand and value where possible and make an inventory of uses where quantification is not possible.

In addition to individual consumers of geologic mapping, society as a whole must be considered as a user because the costs arising from nonuse of geologic information is ultimately borne by the whole society. Collectively, the society must value public goods at least as highly as the costs of the alternatives. So long as the cost of geologic mapping is lower than or equal to the cost of alternatives such as conducting multiple geologic studies by individual users or the cost of cleanup and remedial actions (necessitated by the non-use of geologic information), it is cost effective to conduct geologic mapping.

When benefits and costs concern users of the public good in a limited geographic area, the approach is called "partial equilibrium analysis." When the entire nation or society benefits, the effects of producing or not producing a public good on other segments of the economy and other regions of the nation are also considered; this latter approach is called "general equilibrium analysis." For geologic mapping, elements of general equilibrium analysis are applicable because quantifiable data are available mainly in areas of the economy beyond individual consumers of maps.

Mechanics of Benefit-Cost Assessment

The basic goal of a benefit-cost assessment is to maximize the net benefits or to minimize the net cost. Some public expenditure projects result in positive benefits to society, e.g., a vaccination program that drastically reduces the incidence of a disease. The cost is generally incurred now and the benefits gained later. The most commonly used

approach to assess the benefits and costs is to determine the present value of future benefits and costs whenever they are measurable in dollar amounts and then calculate the B/C ratio.

To determine the present value of benefits or costs in future time periods, the estimated benefits and costs or net benefits are discounted to the present time by using an appropriate annual interest rate or discount rate. When an investment is made in a project like geologic mapping, the investor forgoes the opportunity to invest the same amount in another project. Each one of the other investment opportunities forgone offers a different rate of earnings. Therefore, the geologic mapping project must offer at least as high a rate of earnings, i.e., benefits, as the best alternative. The rate of earnings from the best of the alternatives is called the "opportunity cost." It represents the "discount rate" or the rate at which future net benefits, i.e., benefits minus cost, must be discounted annually to determine the present value of all the future net benefits. If the present value of future net benefits is higher than the original investment, the project should be accepted. Mathematically, the discounting occurs as follows:

$$NB_{pv} = \sum_{i=1}^n \frac{NB_i}{(1+r)^i}$$

NB_{pv} = present value of net benefits

NB_i = net benefits in year i

r = annual discount rate (e.g., $r = 0.1$ for a 10% discount rate)

n = number of years

To determine whether the present value of net benefits is higher than the original investment in geologic mapping, i.e., the original cost, one could subtract the original cost from the present value of net benefits and see if the result is positive. A more commonly used method is to determine the ratio

$$\frac{NB_{pv}}{C_{map}}$$

C_{map} = original cost of mapping program

For public expenditure projects such as geologic mapping, the magnitude of the B/C ratio is only one of the decision-making criteria. A B/C ratio of greater than 1 is not always necessary for a public expenditure project to be undertaken. Social or political considerations may justify execution of a project even when the B/C ratio is less than unity, such as when human lives are in danger or when political necessities require the completion of a project within a constrained time frame or at a particular location.

In this study, the B/C ratio is used to assess geologic mapping programs and supplement quantitative results with narratives concerning the benefits and the costs of the program.

METHODOLOGY USED IN DATA COLLECTION

The cost of geologic mapping in Boone and Winnebago Counties is realistically reflected in the ISGS program budget that was presented to the counties. It consists of three parts: financing by counties provided to the ISGS, direct payments by counties to drilling contractors, and ISGS matching contributions. The 1980 cost figures were recalculated in 1990 dollars to reflect current costs. Social costs resulting from loss of investment opportunities in areas other than geologic mapping are not quantifiable. This omission appears justifiable, however, because a number of benefits also are nonquantifiable and must be excluded from consideration.

Data on benefits attributable to geologic mapping were, by necessity, collected on a case-by-case basis. These are the steps in data collection:

- list potential map users
- determine specific map uses
- interview potential users in Boone and Winnebago Counties
- determine alternative sources used or planned, if maps were unavailable
- monitor costs resulting from nonuse or nonavailability of geologic information.

Before data were collected in Boone and Winnebago Counties, the ISGS mapping committee identified 80 potential map users (institutions, firms, and individuals) in Illinois with the advice of members of the Illinois Geological Mapping Advisory Committee (IGMAC). A questionnaire was developed and mailed to the 80 potential map users to solicit information on how and how often maps are used and of what value the information contained in the maps was to them. Their responses are summarized by Damberger in appendix A. The questionnaire results helped recognize the potential map users in Boone and Winnebago Counties. The list was modified and enhanced with the help of J. Maichle Bacon, Director of the McHenry County Public Health Department, who formerly was Director of Environmental Health in Winnebago County when the geology-for-planning study and the accompanying mapping program was implemented in Boone and Winnebago Counties in 1980-81. Users in the following major categories were contacted subsequently for data collection:

- county planning and public health departments
- city planning departments in Rockford and Belvidere
- mineral extraction companies
- real estate developers
- well drilling contractors
- Illinois Environmental Protection Agency (IEPA), Rockford
- managers of waste water and sewer treatment facilities
- agricultural extension offices
- county highway departments
- geological and engineering consultants.

About 35 individuals were personally visited and data were collected during meetings. Another 20 individuals

were interviewed over the telephone. The format of the interviews, both personal and over the telephone, consistently included the following questions.

- For what purpose are geologic maps used and how often each year?
- Can you quantify the amount of money saved due to availability of geologic maps?
- If you cannot identify dollar savings, can you describe how much time was saved in terms of manpower on an annual basis?
- Do you know of instances where availability of geologic maps would have improved planning and saved money? If yes, in what form (e.g., labor, material, cleanup and remedial costs, transportation costs), and how much?
- How are these savings documented (e.g., records of past or avoidable spending, reliable estimates through feasibility studies, internal estimates by professionals, or estimates by administrative personnel)?
- How accurate were the maps you used? Give the approximate percentage of time that the maps proved accurate.
- What additional map features would you like to see in geologic maps to make them more useful to you?

Answers to these questions enabled the authors to separate the quantifiable savings from nonquantifiable savings. Quantifiable savings can be categorized in levels of decreasing reliability. Different levels of reliability were accommodated in the benefits estimates as described below.

The quantifiable benefits were analyzed for the appropriate level of confidence to be vested in the data. Four categories of benefits were made with decreasing levels of confidence:

Level 1 Highest confidence ($\pm 0\%$ variability) was placed on expenses incurred by the IEPA as of June 30, 1990.

Level 2 A confidence level of $\pm 10\%$ percent was assigned to expenses already incurred but not as well documented as the IEPA expenses.

Level 3 Estimates of cleanup costs available from feasibility studies were assigned a $\pm 30\%$ percent confidence, as is commonly done for any feasibility report.

Level 4 Other estimates by experienced managers were classified into the $\pm 50\%$ percent confidence category.

The confidence levels simply indicate the dollar ranges within which benefits are expected to fluctuate; they do not reflect doubt that such benefits will accrue.

Because most benefits will accrue in the future, and their occurrence will depend upon appropriate and timely use of geologic information, a conservative approach was taken to benefits estimates. No previous studies were available to help assess the extent of delays in benefit realization or the magnitude of benefits expected to be realized. Therefore, benefits were assumed

to be delayed by 10 years due to technical, educational, organizational, and political difficulties in making practical use of the geologic knowledge gained from the mapping program. The delayed benefits for avoidable costs were discounted at a 10-percent annual rate in order to convert the dollar amounts to the 1990 basis. Adjusted benefits were then used to determine the B/C ratio in four benefit categories. Category 1 benefits are the same as level 1 benefits. Subsequent benefit categories include cumulative benefits from the four levels of benefits described above. Thus, category 2 includes benefits from levels 1 and 2, category 3 includes benefits from levels 1, 2, and 3, and category 4 includes benefits from all four levels of confidence.

The quantifiable benefits, separated into three levels of confidence, summed up in four cumulative categories and delayed by 10 years to reflect implementation problems, were further reduced by 50, 75, and 90 percent to take into consideration the future use of geology:

Scenario 1 Benefits (i.e., avoidable costs) were reduced 50 percent on the assumption that no dramatic change from past practices will occur in siting facilities and disposing of wastes. Regulations currently require consideration of geology in siting waste disposal facilities but do not include siting of industrial facilities.

Scenario 2 Benefits were reduced 75 percent to account for regulatory progress and for progress in designing

safer waste disposal facilities that will help prevent contamination problems at many sites.

Scenario 3 Benefits were reduced 90 percent on the assumption that regulatory changes in the near future and the already existing regulations on siting industrial and waste disposal facilities will be highly effective and the design of engineered structures highly successful.

These scenarios reflect the impact of USEPA regulations that (1) do not allow generation of harmful wastes; (2) do not allow harmful wastes that are generated, despite all care taken, to get into the ground (i.e., by improving the design of disposal facilities); and (3) require use of geology for siting so that if the measures described in (1) and (2) fail, the environment is still safe.

The statewide projection of benefits was based on county areas and an aquifer contamination potential score determined for each county using the location of aquifers and the number of sources of potential contamination per square mile.

The statewide projection of mapping cost from the two-county area (\$21 million) was considered low by some experts because of differences in geology and the amount of additional work needed in some other counties. Therefore, the statewide projection of B/C ratios was conducted in two versions: the base case using the two-county mapping costs and an alternative version with higher statewide mapping costs.

SUMMARY OF BENEFITS AND COSTS OF GEOLOGIC MAPPING IN BOONE AND WINNEBAGO COUNTIES

The benefits of geologic mapping programs in Boone and Winnebago Counties are only partially measurable. Detailed geologic maps for the area have existed for only about 10 years. As a result, their use has yet to yield benefits measurable in dollar amounts. Documentable potential benefits—quantifiable and nonquantifiable—do exist however, in the form of expenditures that could have been significantly reduced, and in some instances completely avoided, had the same degree of geologic knowledge existed 25 to 50 years ago. In this section, the costs and benefits of mapping are summarized, and in the following section, the results of the two-county study are extrapolated to the entire state.

Cost of Mapping in Boone and Winnebago Counties

The cost to the counties of conducting this investigation was \$68,919 (\$24,122, Boone County; \$44,797, Winnebago County), payable to the ISGS, plus \$40,065 (\$13,258, Boone County; \$26,807, Winnebago County) in contractual drilling services paid by the counties to independent operators. In addition, the ISGS contributed matching funds covering state-funded personnel, travel and use of ISGS vehicles, ISGS drilling (in addition to county-contracted drilling), and other overhead expenses. The total ISGS contribution was \$65,388 (\$22,885,

Boone County; \$42,503, Winnebago County). Table 1 shows the actual 1980-81 cost and the conversion to 1990 dollars based on actual and estimated expenses.

The costs considered in this section are those directly measurable. Implementation of decisions based on geologic maps can also cause social costs. Such social costs are not measurable at this time because Boone and Winnebago Counties are the first counties to have published maps in detail and cases of map use and the resulting social costs are not documented. A comparison of the nonquantifiable social costs with nonquantifiable benefits will indicate that such benefits are likely to be high enough to offset costs.

Quantifiable Benefits

The most quantifiable evidence of potential benefits comes from waste disposal sites and industrial sites, and some septic and sewer systems in housing and commercial subdivisions. The data sources fall into the following categories:

- federal Superfund sites
- State Remedial Action Priority List (SRAPL) sites
- industrial voluntary cleanup sites
- other uncategorized sites

Table 1 Actual dollar cost of the Boone-Winnebago Counties mapping program in 1980–81 and estimated costs for 1990.

	1980–81			1990		
	Boone	Winnebago	Total	Boone	Winnebago	Total
Counties to ISGS	\$24,122	\$ 44,797	\$ 68,919	\$66,500	\$123,500	\$190,000 ^a
Counties to drillers	13,258	26,807	40,065	23,000 ^b	46,500	69,500
ISGS contribution	22,885	42,503	65,388	10,000	20,000	30,000 ^c
Total	\$60,265	\$114,107	\$174,372	\$99,500	\$190,000	\$289,500

^a Estimate based upon ISGS conducting this mapping program in 1990. Includes some of the amounts originally shown under ISGS contribution in 1980–81.

^b Estimate of real cost made by original Boone County driller; percentage increase (73.48) extrapolated for Winnebago County.

^c Cost includes 25 percent of two state-funded positions for 2 years. Many ISGS contribution costs in 1980–81 would now be part of the cost paid by counties to ISGS.

- septic and sewer systems needing remedial action
- estimates by individuals or firms.

In the two-county area, there are nine federal Superfund sites, three in Boone and six in Winnebago; ten industrial voluntary cleanup sites, one in Boone and nine in Winnebago; two SRAPL sites; and four other sites (appendix B). Not all of these sites are waste disposal sites; many are contaminated industrial sites requiring cleanup action.

The most reliably quantifiable expenses, i.e., potential benefits from map use, incurred on these sites are amounts spent by the IEPA to document and investigate the extent of contamination, and in some cases to take remedial action. Table 2 summarizes the IEPA expenditure by site from appendix B. The exact present value of the IEPA expenditures is difficult to determine because the money was spent over the past several years. It was assumed, conservatively, that all the expenditures were made in 1990.

In addition to IEPA expenditures, the following estimated amounts were spent by federal and state governments on management assistance.

Site name	Amount spent
Bonus (Mig)	\$ 22,000
Beloit Corporation	20,000
IPC	100,000
Total	\$142,000

Although the accuracy of the estimated \$142,000 spent on management assistance is not as high as that of the \$2.5 million spending by the IEPA, the estimates were made by the IEPA and can be considered acceptably close.

State, county, and municipal authorities outlined additional spending for which only estimates are available. Such additional spending included

- money already spent on Remedial Investigation and Feasibility Studies (RIFS),
- money estimated to be needed for RIFS in the future,
- estimates of cleanup costs to be expected in decades to come.

Table 2 IEPA expenditures on Boone-Winnebago sites.

Site name	IEPA expenditure as of June 30, 1990
Belvidere Municipal No. 1	\$ 149,307
Bonus (Mig)	45,651
Parson's Outside	413,487
Midwest Plating	1,461
Pagel's Pit	7,414
Acme Solvents	59,025
Beloit Corporation	12,659
Six Oaks (Pecatonica)	810,506
Illinois Pollution Control (IPC)	10,315
Illinois Water Treatment	2,288
Borg Warner Corp.	14,447
Sunstrand	5,894
Hydrolite	27
Woodward Governor Co.	4,197
Mattison Machine Works	46
Kaney Transportation	1,351
Ipsen CHT	23,364
People's Avenue (Quaker Oats)	2,846
Frink's Industrial Waste	893,143
Total IEPA through June 30, 1990	\$2,478,018

The successive levels of cost estimation decrease in reliability as estimated spending time moves further into the future. On the other hand, future cost of remedial actions to cleanup contaminated groundwater aquifers may exceed estimates contained in the RIFS. Serious concerns have been raised that the commonly used pump-and-treat remedy may not be effective and final costs could be much higher than presumed (Travis and Doty 1990). Tables 3 and 4 summarize the cleanup costs discussed above.

Data in tables 1, 2, and 3 demonstrate the following:

- The IEPA has spent about \$2,478,000 on contamination site studies.
- An additional \$4,742,000 has been spent on RIFS and management assistance.
- RIFS and cleanup expenditures are conservatively assumed to begin in 1992. The expenditures in 1992

Table 3 Estimated cleanup costs of Boone-Winnebago Superfund sites.

Site name	Spent on RIFS	Future estimated spending on RIF	Future estimated cleanup cost		
			Min/yr*	Max/yr	No. of years
Belvidere Municipal No. 1			\$ 500,000	\$ 700,000	10
Bonus (Mig)			1,500,000	1,500,000	30
Parson's Outside	\$1,200,000		2,000,000	3,000,000	25
Pagel's Pit	2,000,000 ^a	— ^b	— ^b		— ^b
Acme Solvents	1,000,000		1,000,000	1,000,000	25
Six Oaks (Pecatonica)			37,000	\$ 37,000	30
Southeast Rockford	400,000		3,550,000 ^c		1
IPC		\$750,000 ^d	1,000,000 ^e		1
Total Superfund sites	\$4,600,000	\$750,000	\$9,587,000		

* Spending conservatively assumed to begin in 1992.

^a \$1.0 million for RIFS and \$1.0 million to plan an alternative site to Pagel's Pit.

^b Despite being declared a Superfund site, Pagel's Pit has been targeted for expansion. Cleanup costs are unknown at this time.

^c Least-cost short-term alternative.

^d Spending is conservatively assumed to begin in 1992.

^e Immediate soil cleanup. Water pump-and-treat remedy will add to the annual expenses.

Table 4 Estimated costs of voluntary cleanup sites and other sites in Boone and Winnebago Counties.

Site name	First year expenses for investigations and remedial action ^a	Recurrent annual expenses	No. of years
Illinois Water Treatment	?	?	?
Warner Brake	\$4,000,000	— ^b	— ^b
Woodward Governor Co.	300,000	unknown	unknown
Kaney Transportation	100,000	unknown	unknown
American Brass	25,000		
Peoples' Avenue (Quaker Oats)	500,000	unknown	unknown
Sand Park	\$2,000,000		

^a Minimum amounts. First year expenses are conservatively assumed to occur in 1992. Estimates by IEPA and county officials.

^b Warner Brake agreed to settle a \$39 million lawsuit by the State Attorney General. Expenses are estimated to be at least \$1 million per year for 10 to 20 years.

alone are estimated to be a minimum of \$10,337,000 from federal and state sources and an additional \$6,925,000 from voluntary industrial spending, totaling \$17,262,000 in current dollars or \$14,266,116 in 1990 dollars when discounted 10 percent annually.

- Cleanup expenses on Superfund sites will continue for 9 to 29 years beyond 1992. Those future expenses are estimated to total \$37,000,000 in 1990 dollars.
- Voluntary cleanup expenses by industry in decades to come are unknown and not included in this study.

Of the various estimated expenses discussed thus far, the only expenses that can be relied upon totally are those already paid for and documented exactly. These are assigned the highest level of confidence, level 1. Expenses already paid for but documented in rounded-off figures are given a ± 10 -percent confidence range and assigned to level 2. Economic feasibility studies are considered by convention to be ± 30 percent accurate in their estimates, while estimates of expected future expenses over several decades have been assigned a ± 50 -percent confi-

dence range due to their lower reliability than that of a feasibility study. The last two estimates are therefore assigned level 3 and level 4. The estimated benefits under levels 1 through 4 are as follows:

- Level 1** ± 0 percent of \$2,478,000 = \$2,478,000
- Level 2** ± 10 percent of \$4,742,000 = \$4,267,800 to \$5,216,200
- Level 3** ± 30 percent of \$14,266,116 = \$9,986,300 to \$18,546,000
- Level 4** ± 50 percent of \$37,000,000 = \$18,500,000 to \$55,500,000

Two crucial questions must be answered: How much of the expenditure estimated in each one of the four levels above could have been avoided had geologic maps existed and been used in the past? What part of these costs may be incurred in the future under improved regulatory procedure and engineered designs of facilities?

With respect to the first question, determination of the usefulness of geologic maps in selecting sites for waste disposal requires an understanding of the criteria

used to estimate the contamination potential. Contamination potential can be negligible where aquifers are deep or nonexistent and it will be very low where relatively impermeable material underlies the site. It is, therefore, not unrealistic to expect that part of the remedial costs as documented above could be avoided and equivalent benefits credited to geologic mapping programs.

Obviously, there is no guarantee that knowledge of geology would have prevented all the above costs. However, two basic statements can be made with confidence.

- Although all problem disposal sites probably could not have been avoided with proper geologic mapping and use of that information, the avoidable costs would have been significantly lower if geology had been used.
- The time of incurring such avoidable costs would have been pushed into the future, perhaps by decades, if geologic mapping had been used. A 10-year delay has been assumed in the present study.

The second question concerns the magnitude of cost reduction, and therefore of potential benefits, which will also depend upon the applicability of environmental regulations already in place and to be put in place. To account for future uncertainties, we offer the following three scenarios.

- About 50 percent of future cleanup costs would be avoided, assuming that past disposal practices will not change dramatically and that there is less than satisfactory use of geology. This base-case scenario appears justified because regulation of industrial sites on a statewide basis requiring consideration of geologic conditions is yet to be introduced.
- About 75 percent of future cleanup work would be unnecessary and the benefits reduced accordingly because environmental regulations in effect today and to be expected in the near future can prevent many of the contaminated sites in the future. Also, knowledge of geo-

logy has contributed to improvements in design and engineering of facilities.

- About 90 percent of the future cleanup work would be unnecessary as statewide regulations for industrial sites are promulgated and implemented, and as improved engineered designs of disposal facilities prove highly successful. This would further reduce the potential benefits from geologic mapping. However, geologic knowledge would be essential for designing facilities that minimize contamination risk.

The present value estimates (in 1990 dollars) of benefits derived in the form of avoided costs under the above three scenarios are summarized in table 5.

The evidence for the economic justifiability of geologic mapping programs in Boone and Winnebago Counties is strong, even without including such items as future industrial expenditures for voluntary cleanup and the other quantifiable items and nonquantifiable benefits discussed below. The B/C ratio is greater than unity for all but category 1 under the most rigorous criterion, i.e., when only 10 percent of the estimated potential benefits are realized, as in scenario 3. The B/C ratio in scenario 3 ranges from 4.7 to 10.9 when major future benefits (avoidable costs) are taken into account in category 4, even after discounting the benefits by 90 percent.

Other quantifiable benefits arise from avoidable costs involved in emergency measures to help residents affected by contamination, the search for new deposits of minerals closer to markets, and other events not easily categorized or quantified. Following is a list of such costs that should be taken into account in computing B/C ratios. These costs would be almost certainly avoidable in their entirety, although they are not included in the ratios computed above.

- The Southeast Rockford Superfund site in Winnebago County required emergency measures. Because of contaminated water wells, at least 250 households were supplied bottled drinking water and carbon

Table 5 Present value of benefits of geologic mapping in Boone and Winnebago Counties and the estimated ratios of benefits to cost of mapping.

Scenario	Category	Levels 1 to 4 present value of benefits	Cumulative present value to costs of mapping ^a	Ratio of cumulative quantifiable benefits
1	1	\$ 477,700	\$ 477,700	1.65
	2	822,700 to 1,005,500	1,300,400 to 1,483,200	4.5 to 5.0
	3	1,925,100 to 3,575,150	3,225,500 to 5,058,350	11.0 to 17.5
	4	3,566,275 to 10,698,800	6,791,775 to 15,757,150	23.5 to 54.5
2	1	238,844	238,844	0.83
	2	411,355 to 502,768	650,199 to 741,612	2.25 to 2.56
	3	962,538 to 1,787,571	1,612,737 to 2,529,183	5.57 to 8.74
	4	1,783,138 to 5,349,413	3,395,875 to 7,878,596	11.73 to 27.2
3	1	95,538	95,538	0.33
	2	164,542 to 201,107	260,080 to 296,645	0.9 to 1.02
	3	385,015 to 715,029	645,095 to 1,011,674	2.22 to 3.49
	4	\$ 713,255 to 2,139,765	\$1,358,350 to 3,151,439	4.69 to 10.89

^a See table 1 for cost of mapping in Boone and Winnebago Counties: \$289,500 in 1990 dollars.

filters for about 2 years. Carbon filter costs were estimated at about \$250,000, but no cost data on bottled water supplies are available. We estimate a minimum of 2 gallons of water per household per day would be necessary, and would cost at least 50 cents per gallon. This results in a total cost of \$182,500 over 2 years. The total emergency aid cost is thus estimated at \$432,500 for this site.

- At the Woodward Governor Company's site in Winnebago County, approximately \$300,000 to \$550,000 was spent to remedy a leaking tank, install a monitoring well, and pay the consultant's fees.

- The city of Rockford had to close down at least five city water wells in the area south of Harrison Avenue. Replacement costs per well are estimated to be \$1.5 million each or about \$7,500,000 total.

- Rockford Sand and Gravel Company used the geologic maps in their search for 50,000 cubic yards of clay needed to cap a landfill. The savings in transportation were estimated at 50 cents per cubic yard or \$25,000 because of proximity of a deposit to the demand location. In addition to these savings, the company estimated that about 1 month of a full-time equivalent of labor was saved because the maps provided information that otherwise would have been developed by the company geologist.

- About 60 incidents of leaking underground storage tanks in Winnebago County need full-scale hydrogeologic investigation and possibly pump-and-treat remedial action. Another 140 leaking tanks exist in the county. According to the IEPA, about 80 percent of underground storage tanks leak. Because no permits are required to install underground tanks, remedial action will be required on a large scale in the future. Proper use of geologic maps could have helped reduce these potential costs. About \$250,000 was spent on one site for study and remediation of 18 leaking underground storage tanks. A consulting company in Rockford estimates that geologic maps save them about 1,000 person-hours, worth at least \$75,000 each year.

- The Winnebago County Health Department reported that in 1989 alone a total of 179 septic systems had to be repaired at an average cost of about \$3,000 per system or a total of \$537,000 that could have been avoided with good knowledge and appropriate use of geology during the system planning stage. The county also spent \$3,000,000 to build a water line to Roscoe, while 250 residences paid a total of about \$1,250,000 for hookups to water and sewer systems.

This list is incomplete because soliciting information from every individual and business affected was impossible. For example, water wells supplying fewer than 25 housing units are not monitored by the IEPA, and the county has neither money nor labor to monitor all wells.

Nonquantifiable Benefits

Public funding for projects is often necessary because benefits accrue to the society as a whole rather than

to a particular private enterprise. Typical examples of such projects are education, infrastructure such as road building, or projects related to environmental or national defense. Often, the nonquantifiable benefits are so far-reaching that they outweigh the near-term quantifiable benefits. This account of the nonquantifiable benefits of the Boone-Winnebago geologic mapping program was taken from interviews with citizens and officials in the two counties.

- Planning of waste disposal sites involves gathering of knowledge about geology, hydrology, and geologic material characteristics. On-site drilling is necessary, followed by laboratory testing of materials. Aquifer depths and groundwater recharge patterns must be considered. This procedure is expensive, requiring screening of multiple sites. In Winnebago County, the process of selecting an alternative for the Pagel's Pit municipal landfill site required \$1,000,000, although geologic maps were available. County planners stated that the process of site selection would have been considerably more expensive without the maps. In addition to the cost-lowering effects, the maps also improved the confidence in the decision-making process, the value of which cannot be measured in dollars.

- In a Winnebago County subdivision, housing development took place in an area underlain by a buried peat bog. Although the layers of soil directly under the homes seemed suitable for septic systems, the underlying bog went unnoticed because geologic maps had not been used. Knowledge of geology can prevent such costly oversights. Decisions made on the basis of such knowledge lead to cost prevention but cannot be documented as benefits.

- Leaking from underground storage tanks is a common problem in the two counties. Only a fraction of these have been identified and remedied. Damage to groundwater and public health as a result of contaminants from yet undetected, leaking tanks is not measurable. Some damage can be prevented with the proper use of geologic information.

- School teachers in Boone and Winnebago Counties are using the geologic maps in courses on science and environment. The increased citizen awareness spreads from the school children to their parents. The benefits of this action are immeasurable. A new generation is being influenced by the knowledge of earth science and how to use geologic maps to mitigate environmental damage. The better-informed decisions of the coming generation can be expected to prevent future costs.

- Producers of sand and gravel and other construction materials in the two counties confirmed the use of geologic maps in their day-to-day planning, although they could not quantify how much money the use of the maps saves them. At Rockford Sand and Gravel Company, geologists attested to using maps to search for new areas containing sand and gravel. The growing demand for construction aggregates in rapidly growing McHenry County to the east presents an incentive to the company

to use the maps in their efforts to find deposits closer to the demand area. The transportation cost savings could amount to at least \$1 per ton compared with current aggregate locations.

- Consulting geologist Roberta Jennings reported that regional geology often constitutes 20 to 25 percent of her reports on waste disposal sites or other study sites. She confirmed that countywide geologic maps are the prime source of information on regional geology. Although the value of such uses of maps cannot be assessed in dollars, it is obviously quite significant. County officials and consultants estimated that in Boone and Winnebago Counties, \$3 to \$4 million is spent on environmental consulting contracts by government and private enterprise annually. Geology plays a prime role in these contracts.

- The provision of geologic information to facilitate public opinion in cases of environmental or zoning issues is an important task. As demonstrated in the case of the Pagel's Pit issue in Winnebago County, geology should play an important role. Unfortunately, with Pagel's Pit, geology was not regarded as a significant factor.

METHODOLOGY FOR STATEWIDE PROJECTION OF STUDY RESULTS

The results of the benefits and costs of the Boone-Winnebago geologic mapping program were projected to the entire state of Illinois. A valid extrapolation depends on these critical factors.

Geologic conditions How do conditions in Boone and Winnebago Counties compare with those in other counties? The geology is important not only from a mineral resource viewpoint, but also with respect to the extent and speed with which contaminants migrate. The risk of environmental damage may vary from one area of the state to another. For example, in some Illinois counties, earthquake and landslide potential may be important. The cost of geologic mapping is dependent upon the geology of the area to be mapped.

Demographics of counties How many people reside in a particular county? Do they live in urban or rural areas, what standard of living prevails, and how fast is the population changing?

Economic conditions What is the type of economic activity prevalent in an area—agriculture, mining, manufacturing, service activities, or residential use of land? These activities directly relate to the number of potential contamination sources and points of consumption of natural resources, such as minerals and water.

An investigation of consumption of construction aggregates in the Chicago area by Bhagwat (1989) indicates that population, employment, interest rates, and the Gross State Product most significantly influence the demand for construction aggregates. Consumption of water can also be presumed to be correlated to population density and industrial activity. Quantifiable benefits in Boone and Winnebago Counties in the area of mineral and water resources could thus be extrapolated

- Boone and Winnebago Counties have developed comprehensive county plans for the year 2000. The plans involve residential and industrial development, as well as mineral resource considerations. The issue of materials supply to Chicago and the effect on employment in Boone and Winnebago Counties were included in the plan. Geologic maps served as an important guideline in plan preparation.

- Application of sewage sludge to agricultural land is common practice in some parts of the counties. The superintendent of the South Beloit waste water treatment plant confirmed that sludge from the plant is applied to agricultural land. An ISGS study (Berg et al. 1987) on application of sludge to agricultural land and its effects on groundwater has been used in Boone and Winnebago Counties in formulating county ordinances.

- Water well drillers commonly use geologic maps as a regional guide. Driller Gerald Rosenquist attested that he uses the existing maps at least 50 percent of the time and that they increase his confidence in well siting.

on the basis of population to other counties. However, quantifiable data were available only for environmental pollution. Initially, the contamination potential within the study area as compared with the rest of the state was taken as the basis for statewide projection of quantifiable data. In an alternative case, the influence of geology on mapping costs was included.

The base case projection relies on a comparison of the vulnerability of geologic materials in Boone and Winnebago Counties to potential contamination with the vulnerability of the other 100 counties in Illinois. The contamination potential stems from waste generators, landfills, and CERCLA (Comprehensive Environmental Resource Conservation Recovery Act or Superfund) sites. Keefer and Berg (1990) evaluated the contamination potential to aquifers in their map, *Potential for Aquifer Recharge in Illinois*. Seven categories showing increasing potential for aquifer recharge or potential for contamination were produced. The highest potential for aquifer contamination occurs in regions that contain a major aquifer (100,000 gpd) within 1.5 m of the surface. The lowest potential for aquifer contamination occurs in regions that have no aquifers within 15 m of the surface and no major aquifer at any depth. This mapping is based on the principle that the closer the aquifer is to the surface, the higher is its potential vulnerability to contamination from waste sources.

The geologic information was combined with information compiled by the Illinois State Water Survey (ISWS) that shows the statewide distribution of waste generators, landfills, and CERCLA sites, per zip code per square mile (Shafer 1985). The resultant map, *Prioritization of Aquifer Recharge Areas in Illinois* (ISGS-ISWS unpublished map on open file), combines aquifer

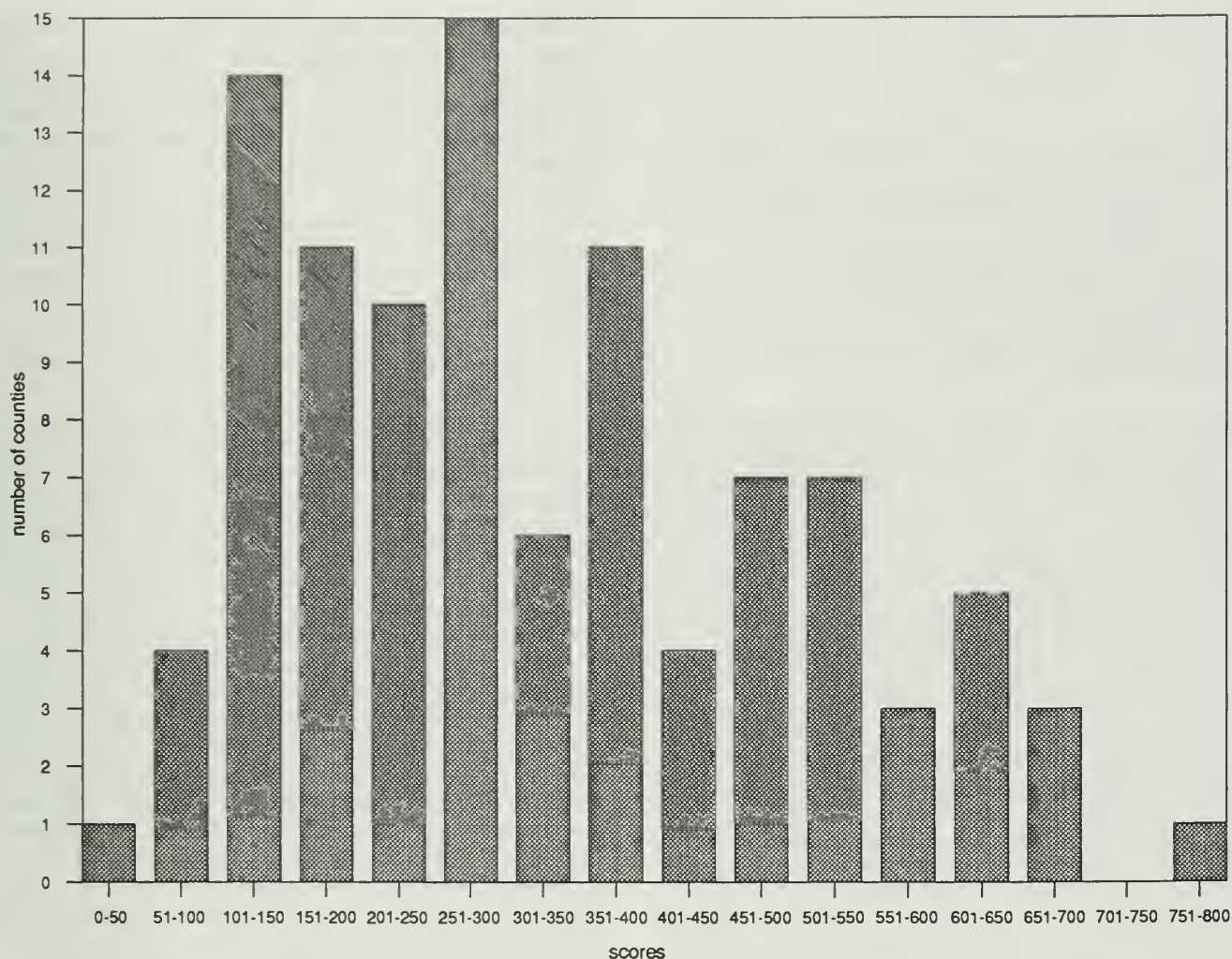


Figure 2 Aquifer contamination potential scores for Illinois counties. Mean score is 320.

vulnerability with the locations of potential contamination sources. Highly vulnerable areas containing numerous potential waste sources are mapped as "very high"; areas containing fewer potential waste sources are ranked lower. Ten map units were produced and ranked from 1 to 10 according to vulnerability. The difference between rank levels is qualitative, e.g., unit number 10 is not necessarily twice as vulnerable as unit number 5.

For each county, the percentage of land area in each rank was calculated and then multiplied by the rank number. For example, if in a county, 54 percent of the land area is classified as rank 10 (weighted partial score $54 \times 10 = 540$), 20 percent as rank 9 (180), 10 percent as rank 8 (80), 8 percent as rank 7 (56), and 8 percent as rank 1 (8), then the weighted total score derived by adding the weighted partial scores would be 864. This calculation of the contamination potential score was done for each county. The score represents the overall potential susceptibility of geologic materials and groundwater within each Illinois county to contamination from waste sources.

The calculated contamination potential score for a given county is a function of aquifer vulnerability, number of potential sources, and the area affected. The higher the score, the greater the contamination potential, and therefore the greater the potential benefits from using geologic maps to prevent contamination.

The methodology of statewide projection of benefits and costs must account for the county score and county size. County scores range from 18 to 796. Figure 2 is the frequency distribution of scores in groups of 50 with the mean score for all Illinois counties at 320.

The contamination potential score incorporates the percentages of county areas with their appropriate rank on a vulnerability scale of 1 to 10, based on sources of contamination per square mile per zip code; but it does not account for the county size in square miles, i.e., the scores are based on percentages of areas, while benefits and costs are also influenced by square miles affected. The following formula for Estimated Total Benefits for the State of Illinois was used to account for the square miles in each vulnerability category.

$$\sum_{i=1}^{102} \left(\frac{B_{bw}}{(A_{bw} \times S_{bw})} \right) A_i \times S_i$$

where

B_{bw} = benefits in Boone and Winnebago Counties in 1990 dollars

A_{bw} = area of Boone and Winnebago Counties in square miles

S_{bw} = sum of contamination potential scores for Boone and Winnebago Counties

A_i = area of county i

S_i = contamination potential score for county i

i = county number 1 to 102

Although contamination potential scores offer one practical basis for extrapolation, their use for statewide estimation of benefits of geologic mapping has limitations. The limitations arise from two sources: (1) The vulnerability rankings are qualitative; for example, areas ranked 6 on vulnerability scale are not necessarily twice as vulnerable as areas ranked 3. (2) The number of potential sources in an area does not reflect the extent of potential contamination unless the amount of effluents from each source is known. Although there is no practical way to quantify the vulnerability rankings relative to one another, there appears to be no other way of accounting for vulnerability to contamination. Therefore, the qualitative vulnerability rankings have been used. The size of the potential source of contamination is of secondary significance because so long as a plant location is attractive to a business, there would be little reason why larger businesses should be concentrated in one location and smaller ones in another. Also, some kinds of businesses with high potential for contaminating the environment may be concentrated in one county, while the same number of other businesses with lower potential for contaminating the environment may be located in another. The resulting contamination potential scores for the two counties may, if the geology were identical, appear to be the same, but in fact will not be. Despite the limitations of the contamination potential scores, the scores represent the best available basis for benefit projection.

RESULTS OF STATEWIDE BENEFIT-COST ESTIMATES

In scenario 1, the benefits and costs of the Boone-Winnebago geologic mapping were projected to the entire state of Illinois using contamination potential scores and county areas. The contamination potential scores account for hydrogeologic conditions and the number of potential sources of contamination in counties. Together with county areas, the contamination potential scores permit a reasonable projection of results from the Boone-Winnebago study to the rest of the state. Table A1 contains the county-by-county results of scenario 1 benefits and costs. In table A1, the counties are listed in descending order of contamination potential scores. The county areas

The cost of geologic mapping in this case is assumed to be primarily dependent upon county size, although the geological complexity and the type of mapping desired may require more or less work. The projection of mapping costs for the state of Illinois was based on the formula

$$\sum_{i=1}^{102} \frac{C_{bw}}{A_{bw}} \times A_i$$

where

C_{bw} = cost of geologic mapping in Boone and Winnebago Counties in 1990 dollars.

The geology of Boone and Winnebago Counties is thought to be sufficiently different from other counties to justify an alternative cost scenario. According to ISGS geologists, the statewide mapping program will include activities that were not undertaken during the Boone-Winnebago geologic mapping program. The statewide mapping program will include expanded data collection, more detailed subsurface and bedrock mapping, extensive computer processing, and the publication of maps of higher resolution (1:24,000 scale) than in Boone and Winnebago Counties. A more intensive program of data collection through field study of outcrops and drilling of stratigraphic control borings is intended, which will allow mapping of Quaternary deposits from the ground surface to depths exceeding 400 feet. Computer processing of data from the archives of government and industry is expected to provide an initial database for the mapping team. Computer technology will be applied to digitize map products and assist in the publication of maps. Digitization of maps is expected to enhance their utility, making it easier to produce derivative map products.

ISGS geologists estimate that the proposed statewide mapping program will cost about \$55,000,000, or 2.6 times the cost estimate in the base case made from the Boone-Winnebago experience. Therefore, the B/C ratios below are presented in two parts: (1) Boone-Winnebago benefits and costs are projected statewide, and (2) in an alternative scenario based on the higher mapping cost, the B/C ratios are calculated again.

are listed in column 3 after the county names. Total benefits and costs for the entire state are listed at the bottom of each column. These sums contain benefits and costs of the Boone-Winnebago study and projections for other counties.

The projected total cost of geologic mapping in 1990 dollars in scenario 1 is about \$21 million. The category 4 benefits of geologic mapping are expected to range from \$127 million to \$295 million.

Category 1 benefits for Boone and Winnebago Counties were assigned the highest confidence level because these benefits were derived from documentable IEPA

spending of the past. The benefits were conservatively assumed to be half the IEPA spending, and to occur with a 10-year delay because not all leaky sites or Superfund sites can be avoided in the future even with the best geologic mapping. On the basis of these assumptions, the projected statewide benefits in category 1 totaled about \$9.0 million (table A1). According to the IEPA, \$55,267,052 was spent statewide as of June 30, 1990. If the same method of benefits estimation discussed above is applied, the statewide category 1 benefits amount to \$10.6 million compared with \$9.0 million as a result of projection of category 1 benefits from Boone and Winnebago Counties to the entire state. The closeness of the two benefit estimates supports the validity of the methodology used in projecting the benefits.

The county-by-county B/C ratios for scenario 1 are listed in descending order in table A2. The statewide B/C ratio in benefit category 4 ranged from 6 to 14. Winnebago and Boone County B/C ratios are not listed because the combined B/C ratio of Boone and Winnebago Counties was discussed previously. Hamilton is the only county with a B/C ratio lower than 1 in category 4.

In table A3, B/C ratios for Illinois counties have been determined under the assumption of a cost increase to \$55 million due to additional work required in other counties. According to table A3, the B/C ratio for category 4 benefits ranges from 2.3 to 5.4 for the entire state.

Scenario 2 projections for the entire state are presented in tables A4, A5, and A6. In this scenario, potential benefits are reduced by 75 percent because of the success of existing environmental regulations and of improved engineering and design of disposal facilities in preventing future contamination. Under scenario 2, the statewide benefits would be \$4.5 million in category 1 and from \$64 million to \$148 million in category 4 (table A4). If the cost of statewide mapping is \$21 million, the

B/C ratios for the entire state would be 0.2 in category 1 and range from 3 to 7 in category 4 (table A5). However, if the cost of mapping increases to \$55 million, the B/C ratio declines to 0.1 in category 1 and to a range of 1.2 to 2.7 in category 4 (table A6). Category 4 B/C ratios indicate that the geologic mapping program for Illinois would pay for itself even when potential benefits are reduced by 75 percent and delayed by 10 years.

In scenario 3, presented in tables A7, A8, and A9, the projections were based on the assumption that 90 percent of the potential benefits (future costs to be avoided) will not materialize because of the effectiveness of current and future environmental regulations and improved engineering design of disposal facilities. The statewide benefits from the geologic mapping program in scenario 3 are projected to be \$2.0 million in category 1 and \$25 million to \$59 million in category 4 (table A7). At the lower mapping cost of \$21 million, the B/C ratio for the entire state would be 0.1 in category 1 and 1.2 to 2.8 in category 4 (table A8). At the higher mapping costs of \$55 million, the ratio would decline to an insignificant level in category 1 and range from 0.5 to 1.1 in category 4 (table A9). The upper range estimate in category 4 remains greater than 1 despite the 90 percent discounting of benefits and exclusion of benefits that are evident but not quantifiable.

The B/C ratios could be used to prioritize counties for geologic mapping. However, B/C ratios cannot be the sole criterion for prioritization. Geologic mapping is most beneficial when conducted in multicounty groupings. Therefore, geographic contiguity should be considered along with the B/C ratios. Other criteria may also alter prioritization if information about the probable occurrence of valuable minerals or geologic hazards such as earthquakes is considered. The B/C ratios will increase if as yet unquantified benefits are considered.

SUMMARY

The benefits and costs of geologic mapping conducted in 1980 in Boone and Winnebago Counties were estimated. The mapping program in 1980 cost about \$174,000, or the equivalent of about \$300,000 in 1990 dollars. The benefits—many unquantifiable—are largely in the form of the ability to use the geologic knowledge to reduce or eliminate some future expenses. Such expenses would include cleanup of contaminated earth materials and groundwater, exploration for minerals, and disposal of urban wastes. Information about future benefits was gained from interviews with 55 individuals in the two counties. The quantifiable benefits data were available only on future estimated cleanup costs for contaminated sites. No other benefits were quantifiable.

The benefits were classified into four levels of variability expected in the estimated dollar amounts: level 1, benefits that were certain (± 0 -percent variability); level

2, ± 10 -percent variability; level 3, ± 30 -percent variability; and level 4, ± 50 -percent variability. The benefits were then grouped into category 1, corresponding to level 1; category 2, including levels 1 and 2; category 3, including levels 1, 2, and 3; and category 4, including benefits of all four levels.

Three benefit scenarios were projected on the basis of applicability and effectiveness of existing and future environmental regulations in preventing future contamination problems. In scenario 1, the benefits were reduced by 50 percent to account for the fact that geologic information may not be used or requirements for siting industrial facilities are not yet in place. In scenario 2, the benefits were reduced by 75 percent under the assumption that some progress will be made in requiring the use of geology in siting industrial facilities, in improving the regulatory procedures, and in designing safer

waste disposal facilities. In scenario 3, the benefits were reduced by 90 percent under the assumption that most of the contamination will be prevented due to the success of existing and expected future regulatory rules on siting industrial and waste disposal facilities, and due to better designs of facilities. Furthermore, the realization of all the benefits was delayed by 10 years to reflect the difficulties in implementing the geologic knowledge gained from the mapping program and any inherent inaccuracies in the data at the scale of compilation. Finally, the benefits were discounted back at a 10-percent annual rate to 1990 and the B/C ratios calculated.

B/C ratios for Boone and Winnebago Counties

	Category 1	Category 4
Scenario 1	1.65	23.5 to 54.5
Scenario 2	0.83	11.7 to 27.2
Scenario 3	0.33	4.7 to 10.9

A statewide projection of Boone and Winnebago County results was based on county areas and a groundwater contamination potential score. The contamination poten-

tial score accounts for the vulnerability of groundwater to contamination and the number of potential sources of contamination per square mile.

Projected statewide B/C ratios

	Category 1		Category 4	
	lower cost	higher cost	lower cost	higher cost
Scenario 1	0.4	0.2	6 to 14	2.3 to 5.4
Scenario 2	0.2	0.1	3 to 7	1.2 to 2.7
Scenario 3	0.1	—	1.2 to 2.8	0.5 to 1.1

The most conservative projection in scenario 3, with the higher cost of mapping, indicates that after reducing the potential future benefits by 90 percent and delaying their realization by 10 years, the benefits in category 4 would range from \$27.5 to \$60.5 million on an investment of \$55 million in statewide geologic mapping. All B/C ratios are based on benefits from avoidance of expenses related only to soil and groundwater contamination. The ratios will increase as numerous other benefits are quantified and included in calculations.

REFERENCES

- Anderson, L. G., and R. F. Settle, 1977, *Benefit Cost Analysis: A Practical Guide*: Lexington Books, D.C. Heath and Company, Lexington, Massachusetts, 140 p.
- Berg, R. C., J. P. Kempton, and A. N. Stecyk, 1984, *Geology for Planning in Boone and Winnebago Counties*: Illinois State Geological Survey, Circular 531, 69 p.
- Berg, R. C., W. J. Morse, and T. M. Johnson, 1987, *Hydrogeologic Evaluation of the Effects of Surface Application of Sewage Sludge to Agricultural Land Near Rockton, Illinois*: Illinois State Geological Survey, Environmental Geology Notes 119, 42 p.
- Bernknopf, R. L., D. S. Brookshire, and M. A. Thayer, 1990, Earthquake and volcano hazard notices: an economic evaluation of changes in risk perceptions: *Journal of Environmental Economics and Management*, v. 18, no. 1, p. 35–49.
- Bernknopf, R. L., R. H. Campbell, D. S. Brookshire, and C. D. Shapiro, 1988, A probabilistic approach to landslide hazard mapping in Cincinnati, Ohio, with applications for economic evaluation: *Bulletin of the Association of Engineering Geologists*, v. 25, no. 1, p. 39–56.
- Bhagwat, S. B., 1989, Model of construction aggregates demand and supply: a Chicago area case study, in R. E. Hughes and J. C. Bradbury, editors, *Proceedings of the 23rd Forum on the Geology of Industrial Minerals*, 11–15 May 1987, North Aurora, Illinois: Illinois State Geological Survey, Illinois Mineral Notes 102, p. 29–34.
- Clapp, J. L., J. D. McLaughlin, J. G. Sullivan, and A. P. Voderhe, 1985, Toward a method for the evaluation of multipurpose land information systems: *Proceedings of Annual URISA Conference*, v. 1, Land Records Systems, p. 1–10.
- Damberger, H. H., 1990, Questionnaire on use of, requirements for, and priorities for geologic maps in Illinois: Illinois State Geological Survey, 6 p.
- Epstein, E. F., and T. D. Duchesneau, 1984, The use and value of a geodetic reference system: University of Maine at Orono, April, Research Report under Grant No. NA82AA-D-00016 for U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 36 p.
- Glahe, F. R., and D. R. Lee, 1981, *Microeconomic Theory and Applications*: Harcourt Brace Jovanovich, New York, p. 139–176, 473–514.
- Keefer, D. A., and R. C. Berg, 1990, Potential for Aquifer Recharge in Illinois: Illinois State Geological Survey, map, scale 1:1,000,000.
- Knight, W. V., 1989, Estimating the value of a geophysical survey: *Leading Edge, Society of Exploration Geophysics*, October, p. 10–12.
- McGrain, P., 1979, An economic evaluation of the Kentucky Geologic Mapping Program: Kentucky Geological Survey, Series XI, p. 12.
- McGrain, P., 1967, The application of new geologic maps to the economic growth of Kentucky: Kentucky Geological Survey, Series 10, Special Publication 14, p. 14–18.
- McGrain, P., 1966, Some economic aspects of Kentucky's geologic mapping program: *Society of Mining Engineers*, preprint 66H301, 10 p.
- Shafer, J. M., 1985, An Assessment of Groundwater Quality and Hazardous Substance for a Statewide Monitoring Strategy (P.A. 83-1268): Illinois State Water Survey, Contract Report 367, 119 p.
- Sugden, R., and A. Williams, 1978, *The Principles of Practical Cost-Benefit Analysis*: Oxford University Press, New York, New York, 275 p.
- Torell, L. A., J. D. Libbin, and M. D. Miller, 1990, The market value of water in the Ogallala Aquifer: *Land Economics*, v. 66, no. 2, p. 163–175.
- Travis, C. C., and C. B. Doty, 1990, Can contaminated aquifers at Superfund sites be remedied? *Environmental Science and Technology*, v. 24, no. 10, p. 1464–1466.
- Treworgy, C., M. Bargh, C. Hindman, and C. Morgan, 1988, Costs and benefits of GIS data management: a case study of a database managed by a state agency: 1988 ACSU-ASPRS Annual Convention, Technical Papers: American Congress on Surveying and Mapping and American Society for Photogrammetry and Remote Sensing, v. 2, p. 186–195.
- U.S. Geological Survey, 1987, Primary mapping economic analysis: phase one, September, 60 p.
- U.S. Geological Survey, 1988, Primary mapping economic analysis: phase two, November, 67 p.
- Willet, B. S., S. Hathorn, Jr., and C. E. Robertson, 1975, The economic value of water used to irrigate field crops in central and southern Arizona: University of Arizona, Department of Agricultural Economics, Report 9, 63 p.

APPENDIX A

PROJECTED BENEFITS AND COSTS OF GEOLOGIC MAPPING PROGRAM FOR ILLINOIS

Table A1 Projected benefits and base case cost of geologic mapping program for Illinois (scenario 1).

No.	Score	County	Area	Category 1,	Estimated cost (1990\$)	Category 2		Category 3		Category 4	
				Estimated benefits (1900\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)	
1	796	Winnebago	516	--	--	--	--	--	--	--	--
2	688	Whiteside	682	231,277	256,391	626,376	715,514	1,553,895	2,438,049	3,274,020	7,593,606
3	682	McHenry	606	203,751	227,820	551,826	630,355	1,368,953	2,147,877	2,884,352	6,689,830
4	673	Alexander	236	78,304	88,722	212,073	242,253	526,105	825,455	1,108,492	2,570,983
5	649	Mason	536	171,516	201,504	464,522	530,627	1,152,371	1,808,062	2,428,019	5,631,433
6	621	Ogle	759	232,444	285,338	629,535	719,123	1,561,732	2,450,345	3,290,533	7,631,906
7	606	Kankakee	679	202,850	255,263	549,386	627,567	1,362,899	2,138,378	2,871,596	6,660,244
8	605	DuPage	337	100,442	126,692	272,031	310,743	674,847	1,058,829	1,421,886	3,297,855
9	605	Rock Island	423	126,043	159,023	341,367	389,946	846,853	1,328,705	1,784,299	4,138,418
10	581	Kane	524	149,994	196,992	406,234	464,045	1,007,773	1,581,189	2,123,355	4,924,809
11	558	Cook	958	263,512	360,150	713,678	815,240	1,770,471	2,777,855	3,730,341	8,651,976
12	557	Stephenson	564	154,792	212,030	419,228	478,887	1,040,007	1,631,763	2,191,271	5,082,330
13	542	Carroll	444	118,592	166,917	321,187	366,895	796,791	1,250,159	1,678,821	3,893,777
14	539	Will	844	224,238	317,293	607,311	693,736	1,506,599	2,363,843	3,174,370	7,362,483
15	522	Monroe	388	99,913	145,865	270,598	309,106	671,291	1,053,250	1,414,394	3,280,477
16	518	Union	414	105,606	155,639	286,017	326,719	709,542	1,113,266	1,494,989	3,467,407
17	513	Mercer	559	141,338	210,150	382,789	437,263	949,612	1,489,934	2,000,810	4,640,585
18	510	Pulaski	203	51,058	76,316	138,283	157,962	343,048	538,240	722,795	1,676,417
19	502	Putnam	160	39,622	60,150	107,311	122,582	266,213	417,686	560,905	1,300,936
20	481	Henry	824	195,262	309,774	528,836	604,093	1,311,919	2,058,391	2,764,183	6,411,114
21	478	Ford	486	114,503	182,707	310,113	354,245	769,319	1,207,056	1,620,938	3,759,526
22	477	JoDavies	603	141,712	226,692	383,804	438,422	952,129	1,493,884	2,006,115	4,652,887
23	475	Lee	725	169,698	272,556	459,598	525,002	1,140,156	1,788,896	2,402,282	5,571,739
24	473	Tazewell	650	151,656	244,361	410,734	469,185	1,018,937	1,598,704	2,146,877	4,979,363
25	451	Bureau	869	193,110	326,692	523,007	597,435	1,297,461	2,035,706	2,733,720	6,340,460
26	450	Lake	454	100,761	170,677	272,894	311,729	676,988	1,062,189	1,426,398	3,308,319
27	424	Boone	282	--	--	--	--	--	--	--	--
28	415	Gallatin	325	66,434	122,180	179,926	205,531	446,355	700,328	940,460	2,181,259
29	409	Johnson	346	69,787	130,075	189,007	215,904	468,883	735,674	987,926	2,291,349
30	406	Grundy	423	84,667	159,023	229,308	261,940	568,860	892,536	1,198,574	2,779,915
31	399	Logan	619	121,809	232,707	329,899	376,846	818,403	1,284,068	1,724,356	3,999,389
32	397	Pike	830	162,311	312,030	439,593	502,151	1,090,530	1,711,032	2,297,720	5,329,224
33	387	Champaign	998	190,452	375,188	515,808	589,212	1,279,601	2,007,684	2,696,090	6,253,183
34	385	Massac	241	45,790	90,602	124,015	141,664	307,653	482,705	648,218	1,503,446
35	385	Hardin	181	34,303	68,045	92,903	106,124	230,472	361,608	485,598	1,126,273
36	380	Henderson	373	69,854	140,226	189,187	216,110	469,329	736,374	988,866	2,293,529
37	374	LaSalle	1139	210,017	428,195	568,795	649,739	1,411,049	2,213,926	2,973,048	6,895,547
38	371	Scott	251	45,846	94,361	124,165	141,835	308,025	483,289	649,002	1,505,265
39	361	Kendall	322	57,287	121,053	155,153	177,232	384,898	603,902	810,971	1,880,927
40	357	Fayette	709	124,772	266,541	337,924	386,013	838,312	1,315,305	1,766,303	4,096,680
41	351	Cass	374	64,747	140,602	175,355	200,310	435,016	682,537	916,569	2,125,848
42	339	Iroquois	1118	186,995	420,301	506,446	578,517	1,256,375	1,971,243	2,647,153	6,139,681
43	333	Pope	374	61,475	140,602	166,494	190,187	413,032	648,044	870,249	2,018,414
44	332	DeWitt	397	64,918	149,248	175,821	200,842	436,171	684,349	919,003	2,131,491
45	328	Jersey	373	60,321	140,226	163,370	186,618	405,282	635,885	853,920	1,980,542
46	322	Lawrence	374	59,397	140,602	160,867	183,759	399,074	626,143	840,839	1,950,202
47	314	Livingston	1046	161,708	393,233	437,959	500,283	1,086,474	1,704,670	2,289,176	5,309,405
48	289	Jackson	590	83,915	221,805	227,271	259,614	563,807	884,609	1,187,929	2,755,225
49	288	DeKalb	634	90,030	238,346	243,831	278,530	604,888	949,065	1,274,485	2,955,980
50	287	Marshall	388	54,879	145,865	148,631	169,782	368,719	578,517	776,882	1,801,864
51	283	Piatt	439	61,136	165,038	165,577	189,140	410,759	644,477	865,459	2,007,305
52	277	Randolph	583	79,523	219,173	215,376	246,025	534,297	838,308	1,125,752	2,611,015
53	275	St. Clair	672	91,004	252,632	246,469	281,544	611,434	959,335	1,288,277	2,987,968
54	269	Greene	543	71,947	204,135	194,858	222,587	483,397	758,446	1,018,506	2,362,274
55	263	White	497	64,331	186,842	174,230	199,025	432,225	678,158	910,688	2,112,207
56	262	Montgomery	705	91,171	265,038	246,922	282,061	612,556	961,095	1,290,641	2,993,451
57	262	Macon	581	75,029	218,421	203,205	232,122	504,104	790,935	1,062,135	2,463,465
58	261	Christian	710	91,384	266,917	247,498	282,719	613,985	963,337	1,293,651	3,000,434
59	261	Woodford	527	67,796	198,120	183,615	209,744	455,505	714,684	959,739	2,225,974
60	257	Stark	288	36,479	108,271	98,798	112,858	245,095	384,552	516,409	1,197,735
61	255	Madison	728	91,472	273,684	247,737	282,992	614,579	964,270	1,294,904	3,003,338
62	252	Williamson	427	52,989	160,526	143,512	163,935	356,020	558,592	750,126	1,739,806
63	248	Calhoun	250	30,557	93,985	82,759	94,536	205,305	322,122	432,572	1,003,288
64	241	Warren	543	64,627	204,135	175,033	199,941	434,216	681,281	914,882	2,121,934
65	238	Crawford	446	52,320	167,669	141,699	161,864	351,523	551,537	740,652	1,717,832
66	236	Clinton	472	54,900	177,444	148,687	169,846	368,858	578,736	777,176	1,802,545
67	227	Washington	563	63,112	211,654	170,928	195,252	424,032	665,303	893,425	2,072,168

Appendix A continued

Table A1 Continued.

No.	Score	County	Area	Category 1,	Estimated cost (1990\$)	Category 2		Category 3		Category 4	
				Estimated benefits (1900\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)	
68	225	Marion	573	63,561	215,414	172,143	196,640	427,047	670,034	899,779	2,086,904
69	221	Menard	315	34,294	118,421	92,880	106,098	230,414	361,518	485,478	1,125,993
70	215	Peoria	621	65,953	233,459	178,622	204,041	443,119	695,251	933,642	2,165,446
71	211	Hancock	796	82,906	299,248	224,538	256,491	557,026	873,970	1,173,641	2,722,087
72	205	McLean	1185	119,532	445,489	323,732	369,802	803,105	1,260,066	1,692,124	3,924,633
73	195	Adams	852	81,801	320,301	221,545	253,073	549,602	862,322	1,158,000	2,685,809
74	189	Wabash	224	20,866	84,211	56,512	64,554	140,194	219,963	295,385	685,103
75	183	Vermilion	900	81,322	338,346	220,246	251,589	546,380	857,266	1,151,210	2,670,062
76	179	Clay	469	41,481	176,316	112,344	128,331	278,698	437,276	587,211	1,361,950
77	172	Knox	720	61,083	270,677	165,432	188,974	410,399	643,913	864,701	2,005,547
78	166	Perry	443	36,150	166,541	97,907	111,840	242,885	381,085	511,754	1,186,938
79	164	Franklin	414	33,555	155,639	90,879	103,812	225,450	353,729	475,018	1,101,734
80	162	Moultrie	325	25,983	122,180	70,370	80,385	174,573	273,903	367,821	853,106
81	159	Edgar	623	48,714	234,211	131,934	150,709	327,298	513,528	689,609	1,599,446
82	155	Clark	506	38,660	190,226	104,705	119,605	259,748	407,543	547,284	1,269,343
83	155	Saline	385	29,355	144,737	79,502	90,816	197,227	309,447	415,552	963,811
84	148	Jefferson	570	41,496	214,286	112,386	128,379	278,803	437,440	587,432	1,362,462
85	142	Wayne	715	50,054	268,797	135,563	154,855	336,301	527,654	708,579	1,643,445
86	141	Brown	306	21,300	115,038	57,686	65,896	143,107	224,533	301,523	699,337
87	138	Jasper	496	33,787	186,466	91,505	104,527	227,003	356,166	478,291	1,109,325
88	137	Douglas	417	28,253	156,767	76,519	87,408	189,826	297,835	399,958	927,644
89	136	Fulton	871	58,579	327,444	158,653	181,230	393,581	617,526	829,266	1,923,360
90	136	Coles	509	34,065	191,353	92,259	105,388	228,874	359,101	482,232	1,118,465
91	133	Sangamon	866	56,574	325,564	153,222	175,027	380,108	596,387	800,879	1,857,521
92	132	Schuyler	436	28,470	163,910	77,107	88,080	191,284	300,124	403,031	934,772
93	119	Morgan	568	33,263	213,534	90,086	102,906	223,483	350,642	470,873	1,092,120
94	111	Richland	360	19,728	135,338	53,430	61,034	132,548	207,966	279,275	647,736
95	110	Effingham	478	25,994	179,699	70,401	80,419	174,648	274,022	367,980	853,474
96	109	Shelby	747	40,008	280,827	108,354	123,774	268,802	421,748	566,360	1,313,588
97	109	Cumberland	346	18,514	130,075	50,142	57,278	124,391	195,168	262,089	607,876
98	83	McDonough	590	24,128	221,805	65,348	74,647	162,112	254,353	341,566	792,213
99	82	Edwards	223	8,978	83,835	24,315	27,775	60,320	94,642	127,093	294,774
100	67	Macoupin	865	28,523	325,188	77,250	88,243	191,639	300,681	403,780	936,507
101	61	Bond	377	11,313	141,729	30,639	34,999	76,008	119,256	160,147	371,437
102	18	Hamilton	436	3,963	163,910	10,733	12,260	26,625	41,774	56,098	130,112
TOTALS				\$8,985,695	\$20,921,429	\$24,336,259	\$27,799,495	\$60,372,642	\$94,724,207	\$127,203,752	\$295,030,335

Appendix A continued

Table A2 Projected B/C ratios by county (scenario 1, lower cost base).

County	Category 1	Category 2 range	Category 3 range	Category 4 range	County	Category 1	Category 2 range	Category 3 range	Category 4 range
Winnebago	--	--	--	--	Crawford	0.3	0.8	1.0	2.1 3.3 4.4 10.2
Whiteside	0.9	2.4	2.8	6.1 9.5 12.8 29.6	Clinton	0.3	0.8	1.0	2.1 3.3 4.4 10.2
McHenry	0.9	2.4	2.8	6.0 9.4 12.7 29.4	Washington	0.3	0.8	0.9	2.0 3.1 4.2 9.8
Alexander	0.9	2.4	2.7	5.9 9.3 12.5 29.0	Marion	0.3	0.8	0.9	2.0 3.1 4.2 9.7
Mason	0.9	2.3	2.6	5.7 9.0 12.0 27.9	Menard	0.3	0.8	0.9	1.9 3.1 4.1 9.5
Ogle	0.8	2.2	2.5	5.5 8.6 11.5 26.7	Peoria	0.3	0.8	0.9	1.9 3.0 4.0 9.3
Kankakee	0.8	2.2	2.5	5.3 8.4 11.2 26.1	Hancock	0.3	0.8	0.9	1.9 2.9 3.9 9.1
DuPage	0.8	2.1	2.5	5.3 8.4 11.2 26.0	McLean	0.3	0.7	0.8	1.8 2.8 3.8 8.8
Rock Island	0.8	2.1	2.5	5.3 8.4 11.2 26.0	Adams	0.3	0.7	0.8	1.7 2.7 3.6 8.4
Kane	0.8	2.1	2.4	5.1 8.0 10.8 25.0	Wabash	0.2	0.7	0.8	1.7 2.6 3.5 8.1
Cook	0.7	2.0	2.3	4.9 7.7 10.4 24.0	Vermilion	0.2	0.7	0.7	1.6 2.5 3.4 7.9
Stephenson	0.7	2.0	2.3	4.9 7.7 10.3 24.0	Clay	0.2	0.6	0.7	1.6 2.5 3.3 7.7
Carroll	0.7	1.9	2.2	4.8 7.5 10.1 23.3	Knox	0.2	0.6	0.7	1.5 2.4 3.2 7.4
Will	0.7	1.9	2.2	4.7 7.5 10.0 23.2	Perry	0.2	0.6	0.7	1.5 2.3 3.1 7.1
Monroe	0.7	1.9	2.1	4.6 7.2 9.7 22.5	Franklin	0.2	0.6	0.7	1.4 2.3 3.1 7.1
Union	0.7	1.8	2.1	4.6 7.2 9.6 22.3	Moultrie	0.2	0.6	0.7	1.4 2.2 3.0 7.0
Mercer	0.7	1.8	2.1	4.5 7.1 9.5 22.1	Edgar	0.2	0.6	0.6	1.4 2.2 2.9 6.8
Pulaski	0.7	1.8	2.1	4.5 7.1 9.5 22.0	Clark	0.2	0.6	0.6	1.4 2.1 2.9 6.7
Putnam	0.7	1.8	2.0	4.4 6.9 9.3 21.6	Saline	0.2	0.5	0.6	1.4 2.1 2.9 6.7
Henry	0.6	1.7	2.0	4.2 6.6 8.9 20.7	Jefferson	0.2	0.5	0.6	1.3 2.0 2.7 6.4
Ford	0.6	1.7	1.9	4.2 6.6 8.9 20.6	Wayne	0.2	0.5	0.6	1.3 2.0 2.6 6.1
JoDaviess	0.6	1.7	1.9	4.2 6.6 8.8 20.5	Brown	0.2	0.5	0.6	1.2 2.0 2.6 6.1
Lee	0.6	1.7	1.9	4.2 6.6 8.8 20.4	Jasper	0.2	0.5	0.6	1.2 1.9 2.6 5.9
Tazewell	0.6	1.7	1.9	4.2 6.5 8.8 20.4	Douglas	0.2	0.5	0.6	1.2 1.9 2.6 5.9
Bureau	0.6	1.6	1.8	4.0 6.2 8.4 19.4	Fulton	0.2	0.5	0.6	1.2 1.9 2.5 5.9
Lake	0.6	1.6	1.8	4.0 6.2 8.4 19.4	Coles	0.2	0.5	0.6	1.2 1.9 2.5 5.8
Boone	--	--	--	--	Sangamon	0.2	0.5	0.5	1.2 1.8 2.5 5.7
Gallatin	0.5	1.5	1.7	3.7 5.7 7.7 17.9	Schuyler	0.2	0.5	0.5	1.2 1.8 2.5 5.7
Johnson	0.5	1.5	1.7	3.6 5.7 7.6 17.6	Morgan	0.2	0.4	0.5	1.0 1.6 2.2 5.1
Grundy	0.5	1.4	1.6	3.6 5.6 7.5 17.5	Richland	0.1	0.4	0.5	1.0 1.5 2.1 4.8
Logan	0.5	1.4	1.6	3.5 5.5 7.4 17.2	Effingham	0.1	0.4	0.4	1.0 1.5 2.0 4.7
Pike	0.5	1.4	1.6	3.5 5.5 7.4 17.1	Shelby	0.1	0.4	0.4	1.0 1.5 2.0 4.7
Champaign	0.5	1.4	1.6	3.4 5.4 7.2 16.7	Cumberland	0.1	0.4	0.4	1.0 1.5 2.0 4.7
Massac	0.5	1.4	1.6	3.4 5.3 7.2 16.6	McDonough	0.1	0.3	0.3	0.7 1.1 1.5 3.6
Hardin	0.5	1.4	1.6	3.4 5.3 7.1 16.6	Edwards	0.1	0.3	0.3	0.7 1.1 1.5 3.5
Henderson	0.5	1.3	1.5	3.3 5.3 7.1 16.4	Macoupin	0.1	0.2	0.3	0.6 0.9 1.2 2.9
LaSalle	0.5	1.3	1.5	3.3 5.2 6.9 16.1	Bond	0.1	0.2	0.2	0.5 0.8 1.1 2.6
Scott	0.5	1.3	1.5	3.3 5.1 6.9 16.0	Hamilton	0.0	0.1	0.1	0.2 0.3 0.3 0.8
Kendall	0.5	1.3	1.5	3.2 5.0 6.7 15.5					
Fayette	0.5	1.3	1.4	3.1 4.9 6.6 15.4	STATE B/C	0.4	1.2	1.3	2.9 4.5 6.1 14.1
Cass	0.5	1.2	1.4	3.1 4.9 6.5 15.1	RATIO				
Iroquois	0.4	1.2	1.4	3.0 4.7 6.3 14.6					
Pope	0.4	1.2	1.4	2.9 4.6 6.2 14.4					
DeWitt	0.4	1.2	1.3	2.9 4.6 6.2 14.3					
Jersey	0.4	1.2	1.3	2.9 4.5 6.1 14.1					
Lawrence	0.4	1.1	1.3	2.8 4.5 6.0 13.9					
Livingston	0.4	1.1	1.3	2.8 4.3 5.8 13.5					
Jackson	0.4	1.0	1.2	2.5 4.0 5.4 12.4					
DeKalb	0.4	1.0	1.2	2.5 4.0 5.3 12.4					
Marshall	0.4	1.0	1.2	2.5 4.0 5.3 12.4					
Piatt	0.4	1.0	1.1	2.5 3.9 5.2 12.2					
Randolph	0.4	1.0	1.1	2.4 3.8 5.1 11.9					
St. Clair	0.4	1.0	1.1	2.4 3.8 5.1 11.8					
Greene	0.4	1.0	1.1	2.4 3.7 5.0 11.6					
White	0.3	0.9	1.1	2.3 3.6 4.9 11.3					
Montgomery	0.3	0.9	1.1	2.3 3.6 4.9 11.3					
Macon	0.3	0.9	1.1	2.3 3.6 4.9 11.3					
Christian	0.3	0.9	1.1	2.3 3.6 4.8 11.2					
Woodford	0.3	0.9	1.1	2.3 3.6 4.8 11.2					
Stark	0.3	0.9	1.0	2.3 3.6 4.8 11.1					
Madison	0.3	0.9	1.0	2.2 3.5 4.7 11.0					
Williamson	0.3	0.9	1.0	2.2 3.5 4.7 10.8					
Calhoun	0.3	0.9	1.0	2.2 3.4 4.6 10.7					
Warren	0.3	0.9	1.0	2.1 3.3 4.5 10.4					

Appendix A continued

Table A3 Projected B/C ratios by county (scenario 1, higher cost base).

County	Category 1	Category 2 range	Category 3 range	Category 4 range	County	Category 1	Category 2 range	Category 3 range	Category 4 range
Winnebago	--	--	--	--	Menard	0.1	0.3	0.3	0.7 1.2 1.6 3.6
Whiteside	0.3	0.9	1.1	2.3 3.6 4.8 11.2	Peoria	0.1	0.3	0.3	0.7 1.1 1.5 3.5
McHenry	0.3	0.9	1.1	2.3 3.6 4.8 11.2	Hancock	0.1	0.3	0.3	0.7 1.1 1.5 3.5
Alexander	0.3	0.9	1.0	2.3 3.5 4.7 11.0	McLean	0.1	0.3	0.3	0.7 1.1 1.4 3.3
Mason	0.3	0.9	1.0	2.2 3.4 4.6 10.6	Adams	0.1	0.3	0.3	0.7 1.0 1.4 3.2
Ogle	0.3	0.8	1.0	2.1 3.3 4.4 10.2	Wabash	0.1	0.3	0.3	0.6 1.0 1.3 3.1
Kankakee	0.3	0.8	0.9	2.0 3.2 4.3 9.9	Vermilion	0.1	0.2	0.3	0.6 1.0 1.3 3.0
DuPage	0.3	0.8	0.9	2.0 3.2 4.3 9.9	Clay	0.1	0.2	0.3	0.6 0.9 1.3 2.9
Rock Island	0.3	0.8	0.9	2.0 3.2 4.3 9.9	Knox	0.1	0.2	0.3	0.6 0.9 1.2 2.8
Kane	0.3	0.8	0.9	1.9 3.0 4.1 9.5	Perry	0.1	0.2	0.3	0.6 0.9 1.2 2.7
Cook	0.3	0.8	0.9	1.9 2.9 3.9 9.1	Franklin	0.1	0.2	0.3	0.6 0.9 1.2 2.7
Stephenson	0.3	0.8	0.9	1.9 2.9 3.9 9.1	Moultrie	0.1	0.2	0.2	0.5 0.9 1.1 2.7
Carroll	0.3	0.7	0.8	1.8 2.8 3.8 8.9	Edgar	0.1	0.2	0.2	0.5 0.8 1.1 2.6
Will	0.3	0.7	0.8	1.8 2.8 3.8 8.8	Clark	0.1	0.2	0.2	0.5 0.8 1.1 2.5
Monroe	0.3	0.7	0.8	1.7 2.7 3.7 8.5	Saline	0.1	0.2	0.2	0.5 0.8 1.1 2.5
Union	0.3	0.7	0.8	1.7 2.7 3.6 8.5	Jefferson	0.1	0.2	0.2	0.5 0.8 1.0 2.4
Mercer	0.3	0.7	0.8	1.7 2.7 3.6 8.4	Wayne	0.1	0.2	0.2	0.5 0.7 1.0 2.3
Pulaski	0.3	0.7	0.8	1.7 2.7 3.6 8.3	Brown	0.1	0.2	0.2	0.5 0.7 1.0 2.3
Putnam	0.3	0.7	0.8	1.7 2.6 3.5 8.2	Jasper	0.1	0.2	0.2	0.5 0.7 1.0 2.3
Henry	0.2	0.6	0.7	1.6 2.5 3.4 7.9	Douglas	0.1	0.2	0.2	0.5 0.7 1.0 2.2
Ford	0.2	0.6	0.7	1.6 2.5 3.4 7.8	Fulton	0.1	0.2	0.2	0.5 0.7 1.0 2.2
JoDaviess	0.2	0.6	0.7	1.6 2.5 3.4 7.8	Coles	0.1	0.2	0.2	0.5 0.7 1.0 2.2
Lee	0.2	0.6	0.7	1.6 2.5 3.3 7.8	Sangamon	0.1	0.2	0.2	0.4 0.7 0.9 2.2
Tazewell	0.2	0.6	0.7	1.6 2.5 3.3 7.7	Schuyler	0.1	0.2	0.2	0.4 0.7 0.9 2.2
Bureau	0.2	0.6	0.7	1.5 2.4 3.2 7.4	Morgan	0.1	0.2	0.2	0.4 0.6 0.8 1.9
Lake	0.2	0.6	0.7	1.5 2.4 3.2 7.4	Richland	0.1	0.1	0.2	0.4 0.6 0.8 1.8
Boone	--	--	--	--	Effingham	0.1	0.1	0.2	0.4 0.6 0.8 1.8
Gallatin	0.2	0.6	0.6	1.4 2.2 2.9 6.8	Shelby	0.1	0.1	0.2	0.4 0.6 0.8 1.8
Johnson	0.2	0.6	0.6	1.4 2.1 2.9 6.7	Cumberland	0.1	0.1	0.2	0.4 0.6 0.8 1.8
Grundy	0.2	0.5	0.6	1.4 2.1 2.9 6.6	McDonough	0.0	0.1	0.1	0.3 0.4 0.6 1.4
Logan	0.2	0.5	0.6	1.3 2.1 2.8 6.5	Edwards	0.0	0.1	0.1	0.3 0.4 0.6 1.3
Pike	0.2	0.5	0.6	1.3 2.1 2.8 6.5	Macoupin	0.0	0.1	0.1	0.2 0.4 0.5 1.1
Champaign	0.2	0.5	0.6	1.3 2.0 2.7 6.3	Bond	0.0	0.1	0.1	0.2 0.3 0.4 1.0
Massac	0.2	0.5	0.6	1.3 2.0 2.7 6.3	Hamilton	0.0	0.0	0.0	0.1 0.1 0.1 0.3
Hardin	0.2	0.5	0.6	1.3 2.0 2.7 6.3					
Henderson	0.2	0.5	0.6	1.3 2.0 2.7 6.2	STATE B/C	0.2	0.4	0.5	1.1 1.7 2.3 5.4
LaSalle	0.2	0.5	0.6	1.3 2.0 2.6 6.1	RATIO				
Scott	0.2	0.5	0.6	1.2 1.9 2.6 6.1					
Kendall	0.2	0.5	0.6	1.2 1.9 2.5 5.9					
Fayette	0.2	0.5	0.5	1.2 1.9 2.5 5.8					
Cass	0.2	0.5	0.5	1.2 1.8 2.5 5.7					
Iroquois	0.2	0.5	0.5	1.1 1.8 2.4 5.5					
Pope	0.2	0.4	0.5	1.1 1.8 2.4 5.5					
DeWitt	0.2	0.4	0.5	1.1 1.7 2.3 5.4					
Jersey	0.2	0.4	0.5	1.1 1.7 2.3 5.4					
Lawrence	0.2	0.4	0.5	1.1 1.7 2.3 5.3					
Livingston	0.2	0.4	0.5	1.0 1.6 2.2 5.1					
Jackson	0.1	0.4	0.4	1.0 1.5 2.0 4.7					
DeKalb	0.1	0.4	0.4	1.0 1.5 2.0 4.7					
Marshall	0.1	0.4	0.4	1.0 1.5 2.0 4.7					
Piatt	0.1	0.4	0.4	0.9 1.5 2.0 4.6					
Randolph	0.1	0.4	0.4	0.9 1.5 2.0 4.5					
St. Clair	0.1	0.4	0.4	0.9 1.4 1.9 4.5					
Greene	0.1	0.4	0.4	0.9 1.4 1.9 4.4					
White	0.1	0.4	0.4	0.9 1.4 1.9 4.3					
Montgomery	0.1	0.4	0.4	0.9 1.4 1.8 4.3					
Macon	0.1	0.4	0.4	0.9 1.4 1.8 4.3					
Christian	0.1	0.4	0.4	0.9 1.4 1.8 4.3					
Woodford	0.1	0.4	0.4	0.9 1.4 1.8 4.3					
Stark	0.1	0.3	0.4	0.9 1.3 1.8 4.2					
Madison	0.1	0.3	0.4	0.9 1.3 1.8 4.2					
Williamson	0.1	0.3	0.4	0.8 1.3 1.8 4.1					
Calhoun	0.1	0.3	0.4	0.8 1.3 1.7 4.1					
Warren	0.1	0.3	0.4	0.8 1.3 1.7 3.9					
Crawford	0.1	0.3	0.4	0.8 1.2 1.7 3.9					
Clinton	0.1	0.3	0.4	0.8 1.2 1.7 3.9					
Washington	0.1	0.3	0.4	0.8 1.2 1.6 3.7					
Marion	0.1	0.3	0.3	0.8 1.2 1.6 3.7					

Appendix A continued

Table A4 Projected benefits and cost of geologic mapping program for Illinois (scenario 2).

No.	Score	County	Area	Category 1		Category 2		Category 3		Category 4	
				Estimated benefits (1900\$)	Estimated cost (1990\$)	Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)	
1	796	Winnebago	516	--	193,985	--	--	--	--	--	--
2	688	Whiteside	682	115,639	256,391	313,188	357,516	777,188	1,219,024	1,636,287	3,796,803
3	682	McHenry	606	101,876	227,820	275,913	314,965	684,689	1,073,938	1,441,539	3,344,915
4	673	Alexander	236	39,152	88,722	106,037	121,045	263,134	412,728	554,001	1,285,492
5	649	Mason	536	85,758	201,504	232,261	265,135	576,364	904,031	1,213,474	2,815,716
6	621	Ogle	759	116,222	285,338	314,768	359,319	781,108	1,225,173	1,644,540	3,815,953
7	606	Kankakee	679	101,425	255,263	274,693	313,572	681,661	1,069,189	1,435,164	3,330,122
8	605	DuPage	337	50,221	126,692	136,016	155,267	337,528	529,415	710,629	1,648,928
9	605	Rock Island	423	63,022	159,023	170,683	194,842	423,558	664,353	891,755	2,069,209
10	581	Kane	524	74,997	196,992	203,117	231,866	504,043	790,594	1,061,209	2,462,405
11	558	Cook	958	131,756	360,150	356,839	407,346	885,510	1,388,928	1,864,347	4,325,988
12	557	Stephenson	564	77,396	212,030	209,614	239,282	520,165	815,882	1,095,152	2,541,165
13	542	Carroll	444	59,296	166,917	160,594	183,324	398,519	625,080	839,040	1,946,888
14	539	Will	844	112,119	317,293	303,656	346,635	753,533	1,181,921	1,586,484	3,681,241
15	522	Monroe	388	49,957	145,865	135,299	154,449	335,749	526,625	706,885	1,640,239
16	518	Union	414	52,803	155,639	143,009	163,250	354,881	556,633	747,165	1,733,703
17	513	Mercer	559	70,669	210,150	191,395	218,484	474,953	744,967	999,964	2,320,292
18	510	Pulaski	203	25,529	76,316	69,142	78,928	171,577	269,120	361,238	838,208
19	502	Putnam	160	19,811	60,150	53,655	61,250	133,148	208,843	280,329	650,468
20	481	Henry	824	97,631	309,774	264,418	301,843	656,163	1,029,195	1,381,481	3,205,557
21	478	Ford	486	57,252	182,707	155,057	177,003	384,779	603,528	810,111	1,879,763
22	477	JoDaviess	603	70,856	226,692	191,902	219,064	476,212	746,942	1,002,614	2,326,443
23	475	Lee	725	84,849	272,556	229,799	262,324	570,255	894,448	1,200,611	2,785,870
24	473	Tazewell	650	75,828	244,361	205,367	234,434	509,626	799,352	1,072,964	2,489,682
25	451	Bureau	869	96,555	326,692	261,504	298,517	648,932	1,017,853	1,366,256	3,170,230
26	450	Lake	454	50,380	170,677	136,447	155,760	338,599	531,094	712,884	1,654,160
27	424	Boone	282	--	106,015	--	--	--	--	--	--
28	415	Gallatin	325	33,217	122,180	89,963	102,696	223,247	350,164	470,023	1,090,630
29	409	Johnson	346	34,894	130,075	94,504	107,880	234,514	367,837	493,745	1,145,675
30	406	Grundy	423	42,334	159,023	114,654	130,882	284,518	446,268	599,022	1,389,958
31	399	Logan	619	60,904	232,707	164,949	188,296	409,328	642,034	861,797	1,999,694
32	397	Pike	830	81,156	312,030	219,797	250,906	545,434	855,516	1,148,353	2,664,612
33	387	Champaign	998	95,226	375,188	257,904	294,407	639,999	1,003,842	1,347,450	3,126,592
34	385	Massac	241	22,895	90,602	62,008	70,784	153,874	241,353	323,966	751,723
35	385	Hardin	181	17,151	68,045	46,452	53,026	115,272	180,804	242,692	563,137
36	380	Henderson	373	34,927	140,226	94,594	107,982	234,737	368,187	494,215	1,146,764
37	374	LaSalle	1139	105,008	428,195	284,398	324,651	705,744	1,106,963	1,485,868	3,447,774
38	371	Scott	251	22,923	94,361	62,083	70,870	154,060	241,645	324,358	752,632
39	361	Kendall	322	28,644	121,053	77,576	88,556	192,509	301,951	405,306	940,463
40	357	Fayette	709	62,386	266,541	168,962	192,877	419,286	657,652	882,762	2,048,340
41	351	Cass	374	32,373	140,602	87,678	100,087	217,576	341,269	458,082	1,062,924
42	339	Iroquois	1118	93,498	420,301	253,223	289,064	628,382	985,621	1,322,992	3,069,840
43	333	Pope	374	30,737	140,602	83,247	95,029	206,580	324,022	434,932	1,009,207
44	332	DeWitt	397	32,459	149,248	87,910	100,353	218,153	342,175	459,298	1,065,745
45	328	Jersey	373	30,161	140,226	81,685	93,246	202,704	317,942	426,772	990,271
46	322	Lawrence	374	29,699	140,602	80,433	91,818	199,599	313,072	420,234	975,101
47	314	Livingston	1046	80,854	393,233	218,979	249,973	543,406	852,335	1,144,083	2,654,703
48	289	Jackson	590	41,958	221,805	113,636	129,719	281,991	442,305	593,702	1,377,612
49	288	DeKalb	634	45,015	238,346	121,915	139,171	302,538	474,532	636,961	1,477,990
50	287	Marshall	388	27,440	145,865	74,315	84,834	184,417	289,259	388,270	900,932
51	283	Piatt	439	30,568	165,038	82,789	94,506	205,443	322,239	432,539	1,003,653
52	277	Randolph	583	39,762	219,173	107,688	122,930	267,231	419,154	562,627	1,305,508
53	275	St. Clair	672	45,502	252,632	123,235	140,677	305,812	479,667	643,854	1,493,984
54	269	Greene	543	35,974	204,135	97,429	111,219	241,773	379,223	509,028	1,181,137
55	263	White	497	32,166	186,842	87,115	99,445	216,180	339,079	455,143	1,056,104
56	262	Montgomery	705	45,586	265,038	123,461	140,935	306,373	480,548	645,036	1,496,726
57	262	Macon	581	37,515	218,421	101,602	115,983	252,130	395,467	530,833	1,231,732
58	261	Christian	710	45,692	266,917	123,749	141,264	307,088	481,669	646,540	1,500,217
59	261	Woodford	527	33,898	198,120	91,807	104,802	227,823	357,342	479,658	1,112,987
60	257	Stark	288	18,240	108,271	49,399	56,391	122,585	192,276	258,091	598,867
61	255	Madison	728	45,736	273,684	123,869	141,401	307,385	482,135	647,166	1,501,669
62	252	Williamson	427	26,495	160,526	71,756	81,912	178,065	279,296	374,897	869,903
63	248	Calhoun	250	15,278	93,985	41,379	47,236	102,684	161,061	216,191	501,644
64	241	Warren	543	32,314	204,135	87,516	99,903	217,175	340,640	457,239	1,060,967
65	238	Crawford	446	26,160	167,669	70,850	80,878	175,816	275,769	370,162	858,916
66	236	Clinton	472	27,450	177,444	74,344	84,866	184,486	289,368	388,416	901,272

Appendix A *continued*

Table A4 *Continued.*

No.	Score	County	Area	Category 1,		Category 2		Category 3		Category 4	
				Estimated benefits (1900\$)	Estimated cost (1990\$)	Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)	
67	227	Washington	563	31,556	211,654	85,464	97,560	212,082	332,651	446,515	1,036,084
68	225	Marion	573	31,780	215,414	86,072	98,254	213,590	335,017	449,691	1,043,452
69	221	Menard	315	17,147	118,421	46,440	53,013	115,243	180,759	242,632	562,997
70	215	Peoria	621	32,976	233,459	89,311	101,952	221,628	347,626	466,615	1,082,723
71	211	Hancock	796	41,453	299,248	112,269	128,159	278,599	436,985	586,561	1,361,044
72	205	McLean	1185	59,766	445,489	161,866	184,776	401,677	630,033	845,689	1,962,316
73	195	Adams	852	40,901	320,301	110,773	126,451	274,886	431,161	578,744	1,342,905
74	189	Wabash	224	10,433	84,211	28,256	32,255	70,119	109,982	147,627	342,551
75	183	Vermilion	900	40,661	338,346	110,123	125,710	273,275	428,633	575,351	1,335,031
76	179	Clay	469	20,740	176,316	56,172	64,122	139,392	218,638	293,476	680,975
77	172	Knox	720	30,541	270,677	82,716	94,424	205,263	321,956	432,160	1,002,773
78	166	Perry	443	18,075	166,541	48,954	55,882	121,480	190,543	255,764	593,469
79	164	Franklin	414	16,778	155,639	45,440	51,871	112,760	176,865	237,404	550,867
80	162	Moultrie	325	12,991	122,180	35,185	40,165	87,313	136,952	183,829	426,553
81	159	Edgar	623	24,357	234,211	65,967	75,304	163,700	256,764	344,652	799,723
82	155	Clark	506	19,330	190,226	52,352	59,762	129,914	203,772	273,521	634,672
83	155	Saline	385	14,677	144,737	39,751	45,377	98,644	154,723	207,684	481,906
84	148	Jefferson	570	20,748	214,286	56,193	64,146	139,445	218,720	293,586	681,231
85	142	Wayne	715	25,027	268,797	67,782	77,375	168,203	263,827	354,133	821,722
86	141	Brown	306	10,650	115,038	28,843	32,926	71,576	112,267	150,695	349,669
87	138	Jasper	496	16,893	186,466	45,753	52,228	113,537	178,083	239,040	554,662
88	137	Douglas	417	14,127	156,767	38,259	43,675	94,942	148,917	199,891	463,822
89	136	Fulton	871	29,290	327,444	79,326	90,554	196,852	308,763	414,450	961,680
90	136	Coles	509	17,032	191,353	46,130	52,659	114,472	179,551	241,009	559,233
91	133	Sangamon	866	28,287	325,564	76,611	87,454	190,113	298,193	400,263	928,761
92	132	Schuyler	436	14,235	163,910	38,553	44,010	95,672	150,062	201,427	467,386
93	119	Morgan	568	16,631	213,534	45,043	51,418	111,776	175,321	235,332	546,060
94	111	Richland	360	9,864	135,338	26,715	30,496	66,294	103,983	139,576	323,868
95	110	Effingham	478	12,997	179,699	35,200	40,183	87,351	137,011	183,909	426,737
96	109	Shelby	747	20,004	280,827	54,177	61,845	134,443	210,874	283,055	656,794
97	109	Cumberland	346	9,257	130,075	25,071	28,620	62,215	97,584	130,986	303,938
98	83	McDonough	590	12,064	221,805	32,674	37,298	81,081	127,176	170,708	396,107
99	82	Edwards	223	4,489	83,835	12,158	13,878	30,169	47,321	63,519	147,387
100	67	Macoupin	865	14,262	325,188	38,625	44,092	95,849	150,340	201,801	468,254
101	61	Bond	377	5,656	141,729	15,319	17,488	38,016	59,628	80,038	185,718
102	18	Hamilton	436	1,981	163,910	5,366	6,126	13,317	20,887	28,037	65,056
TOTALS				\$4,492,848	\$20,921,429	\$12,168,129	\$13,890,388	\$30,195,681	\$47,362,103	\$63,573,796	\$147,515,167

Appendix A continued

Table A5 Projected B/C ratios by county (scenario 2, lower cost base).

County	Category 1	Category 2 range	Category 3 range	Category 4 range	County	Category 1	Category 2 range	Category 3 range	Category 4 range
Winnebago	--	--	--	--	Menard	0.1	0.4	0.4	1.0 1.5 2.0 4.8
Whiteside	0.5	1.2	1.4	3.0 4.8 6.4 14.8	Peoria	0.1	0.4	0.4	0.9 1.5 2.0 4.6
McHenry	0.4	1.2	1.4	3.0 4.7 6.3 14.7	Hancock	0.1	0.4	0.4	0.9 1.5 2.0 4.5
Alexander	0.4	1.2	1.4	3.0 4.7 6.2 14.5	McLean	0.1	0.4	0.4	0.9 1.4 1.9 4.4
Mason	0.4	1.2	1.3	2.9 4.5 6.0 14.0	Adams	0.1	0.3	0.4	0.9 1.3 1.8 4.2
Ogle	0.4	1.1	1.3	2.7 4.3 5.8 13.4	Wabash	0.1	0.3	0.4	0.8 1.3 1.8 4.1
Kankakee	0.4	1.1	1.2	2.7 4.2 5.6 13.0	Vermilion	0.1	0.3	0.4	0.8 1.3 1.7 3.9
DuPage	0.4	1.1	1.2	2.7 4.2 5.6 13.0	Clay	0.1	0.3	0.4	0.8 1.2 1.7 3.9
Rock Island	0.4	1.1	1.2	2.7 4.2 5.6 13.0	Knox	0.1	0.3	0.3	0.8 1.2 1.6 3.7
Kane	0.4	1.0	1.2	2.6 4.0 5.4 12.5	Perry	0.1	0.3	0.3	0.7 1.1 1.5 3.6
Cook	0.4	1.0	1.1	2.5 3.9 5.2 12.0	Franklin	0.1	0.3	0.3	0.7 1.1 1.5 3.5
Stephenson	0.4	1.0	1.1	2.5 3.8 5.2 12.0	Moultrie	0.1	0.3	0.3	0.7 1.1 1.5 3.5
Carroll	0.4	1.0	1.1	2.4 3.7 5.0 11.7	Edgar	0.1	0.3	0.3	0.7 1.1 1.5 3.4
Will	0.4	1.0	1.1	2.4 3.7 5.0 11.6	Clark	0.1	0.3	0.3	0.7 1.1 1.4 3.3
Monroe	0.3	0.9	1.1	2.3 3.6 4.8 11.2	Saline	0.1	0.3	0.3	0.7 1.1 1.4 3.3
Union	0.3	0.9	1.0	2.3 3.6 4.8 11.1	Jefferson	0.1	0.3	0.3	0.7 1.0 1.4 3.2
Mercer	0.3	0.9	1.0	2.3 3.5 4.8 11.0	Wayne	0.1	0.3	0.3	0.6 1.0 1.3 3.1
Pulaski	0.3	0.9	1.0	2.2 3.5 4.7 11.0	Brown	0.1	0.3	0.3	0.6 1.0 1.3 3.0
Putnam	0.3	0.9	1.0	2.2 3.5 4.7 10.8	Jasper	0.1	0.2	0.3	0.6 1.0 1.3 3.0
Henry	0.3	0.9	1.0	2.1 3.3 4.5 10.3	Douglas	0.1	0.2	0.3	0.6 0.9 1.3 3.0
Ford	0.3	0.8	1.0	2.1 3.3 4.4 10.3	Fulton	0.1	0.2	0.3	0.6 0.9 1.3 2.9
JoDaviess	0.3	0.8	1.0	2.1 3.3 4.4 10.3	Coles	0.1	0.2	0.3	0.6 0.9 1.3 2.9
Lee	0.3	0.8	1.0	2.1 3.3 4.4 10.2	Sangamon	0.1	0.2	0.3	0.6 0.9 1.2 2.9
Tazewell	0.3	0.8	1.0	2.1 3.3 4.4 10.2	Schuyler	0.1	0.2	0.3	0.6 0.9 1.2 2.9
Bureau	0.3	0.8	0.9	2.0 3.1 4.2 9.7	Morgan	0.1	0.2	0.2	0.5 0.8 1.1 2.6
Lake	0.3	0.8	0.9	2.0 3.1 4.2 9.7	Richland	0.1	0.2	0.2	0.5 0.8 1.0 2.4
Boone	--	--	--	--	Effingham	0.1	0.2	0.2	0.5 0.8 1.0 2.4
Gallatin	0.3	0.7	0.8	1.8 2.9 3.8 8.9	Shelby	0.1	0.2	0.2	0.5 0.8 1.0 2.3
Johnson	0.3	0.7	0.8	1.8 2.8 3.8 8.8	Cumberland	0.1	0.2	0.2	0.5 0.8 1.0 2.3
Grundy	0.3	0.7	0.8	1.8 2.8 3.8 8.7	McDonough	0.1	0.1	0.2	0.4 0.6 0.8 1.8
Logan	0.3	0.7	0.8	1.8 2.8 3.7 8.6	Edwards	0.1	0.1	0.2	0.4 0.6 0.8 1.8
Pike	0.3	0.7	0.8	1.7 2.7 3.7 8.5	Macoupin	0.0	0.1	0.1	0.3 0.5 0.6 1.4
Champaign	0.3	0.7	0.8	1.7 2.7 3.6 8.3	Bond	0.0	0.1	0.1	0.3 0.4 0.6 1.3
Massac	0.3	0.7	0.8	1.7 2.7 3.6 8.3	Hamilton	0.0	0.0	0.0	0.1 0.1 0.2 0.4
Hardin	0.3	0.7	0.8	1.7 2.7 3.6 8.3					
Henderson	0.2	0.7	0.8	1.7 2.6 3.5 8.2	STATE B/C	0.2	0.3	0.7	1.4 2.3 3 7.1
LaSalle	0.2	0.7	0.8	1.6 2.6 3.5 8.1	RATIO				
Scott	0.2	0.7	0.8	1.6 2.6 3.4 8.0					
Kendall	0.2	0.6	0.7	1.6 2.5 3.3 7.8					
Fayette	0.2	0.6	0.7	1.6 2.5 3.3 7.7					
Cass	0.2	0.6	0.7	1.5 2.4 3.3 7.6					
Iroquois	0.2	0.6	0.7	1.5 2.3 3.1 7.3					
Pope	0.2	0.6	0.7	1.5 2.3 3.1 7.2					
DeWitt	0.2	0.6	0.7	1.5 2.3 3.1 7.1					
Jersey	0.2	0.6	0.7	1.4 2.3 3.0 7.1					
Lawrence	0.2	0.6	0.7	1.4 2.2 3.0 6.9					
Livingston	0.2	0.6	0.6	1.4 2.2 2.9 6.8					
Jackson	0.2	0.5	0.6	1.3 2.0 2.7 6.2					
DeKalb	0.2	0.5	0.6	1.3 2.0 2.7 6.2					
Marshall	0.2	0.5	0.6	1.3 2.0 2.7 6.2					
Piatt	0.2	0.5	0.6	1.2 2.0 2.6 6.1					
Randolph	0.2	0.5	0.6	1.2 1.9 2.6 6.0					
St. Clair	0.2	0.5	0.6	1.2 1.9 2.5 5.9					
Greene	0.2	0.5	0.5	1.2 1.9 2.5 5.8					
White	0.2	0.5	0.5	1.2 1.8 2.4 5.7					
Montgomery	0.2	0.5	0.5	1.2 1.8 2.4 5.6					
Macon	0.2	0.5	0.5	1.2 1.8 2.4 5.6					
Christian	0.2	0.5	0.5	1.2 1.8 2.4 5.6					
Woodford	0.2	0.5	0.5	1.1 1.8 2.4 5.6					
Stark	0.2	0.5	0.5	1.1 1.8 2.4 5.5					
Madison	0.2	0.5	0.5	1.1 1.8 2.4 5.5					
Williamson	0.2	0.4	0.5	1.1 1.7 2.3 5.4					
Calhoun	0.2	0.4	0.5	1.1 1.7 2.3 5.3					
Warren	0.2	0.4	0.5	1.1 1.7 2.2 5.2					
Crawford	0.2	0.4	0.5	1.0 1.6 2.2 5.1					
Clinton	0.2	0.4	0.5	1.0 1.6 2.2 5.1					
Washington	0.1	0.4	0.5	1.0 1.6 2.1 4.9					
Marion	0.1	0.4	0.5	1.0 1.6 2.1 4.8					

Appendix A continued

Table A6 Projected B/C ratios by county (scenario 2, higher cost base).

County	Category 1	Category 2 range	Category 3 range	Category 4 range	County	Category 1	Category 2 range	Category 3 range	Category 4 range
Winnebago	--	--	--	--	Menard	0.1	0.1	0.2	0.4
Whiteside	0.2	0.5	0.5	1.2	Peoria	0.1	0.1	0.2	0.4
McHenry	0.2	0.5	0.5	1.1	Hancock	0.1	0.1	0.2	0.4
Alexander	0.2	0.5	0.5	1.1	McLean	0.1	0.1	0.2	0.3
Mason	0.2	0.4	0.5	1.1	Adams	0.0	0.1	0.1	0.3
Ogle	0.2	0.4	0.5	1.0	Wabash	0.0	0.1	0.1	0.3
Kankakee	0.2	0.4	0.5	1.0	Vermilion	0.0	0.1	0.1	0.3
DuPage	0.2	0.4	0.5	1.0	Clay	0.0	0.1	0.1	0.3
Rock Island	0.2	0.4	0.5	1.0	Knox	0.0	0.1	0.1	0.3
Kane	0.1	0.4	0.4	1.0	Perry	0.0	0.1	0.1	0.3
Cook	0.1	0.4	0.4	0.9	Franklin	0.0	0.1	0.1	0.3
Stephenson	0.1	0.4	0.4	0.9	Moultrie	0.0	0.1	0.1	0.3
Carroll	0.1	0.4	0.4	0.9	Edgar	0.0	0.1	0.1	0.3
Will	0.1	0.4	0.4	0.9	Clark	0.0	0.1	0.1	0.3
Monroe	0.1	0.4	0.4	0.9	Saline	0.0	0.1	0.1	0.3
Union	0.1	0.3	0.4	0.9	Jefferson	0.0	0.1	0.1	0.2
Mercer	0.1	0.3	0.4	0.9	Wayne	0.0	0.1	0.1	0.2
Pulaski	0.1	0.3	0.4	0.9	Brown	0.0	0.1	0.1	0.2
Putnam	0.1	0.3	0.4	0.8	Jasper	0.0	0.1	0.1	0.2
Henry	0.1	0.3	0.4	0.8	Douglas	0.0	0.1	0.1	0.2
Ford	0.1	0.3	0.4	0.8	Fulton	0.0	0.1	0.1	0.2
JoDaviess	0.1	0.3	0.4	0.8	Coles	0.0	0.1	0.1	0.2
Lee	0.1	0.3	0.4	0.8	Sangamon	0.0	0.1	0.1	0.2
Tazewell	0.1	0.3	0.4	0.8	Schuyler	0.0	0.1	0.1	0.2
Bureau	0.1	0.3	0.3	0.8	Morgan	0.0	0.1	0.1	0.2
Lake	0.1	0.3	0.3	0.8	Richland	0.0	0.1	0.1	0.2
Boone	--	--	--	--	Effingham	0.0	0.1	0.1	0.2
Gallatin	0.1	0.3	0.3	0.7	Shelby	0.0	0.1	0.1	0.2
Johnson	0.1	0.3	0.3	0.7	Cumberland	0.0	0.1	0.1	0.2
Grundy	0.1	0.3	0.3	0.7	McDonough	0.0	0.1	0.1	0.1
Logan	0.1	0.3	0.3	0.7	Edwards	0.0	0.1	0.1	0.1
Pike	0.1	0.3	0.3	0.7	Macoupin	0.0	0.0	0.1	0.1
Champaign	0.1	0.3	0.3	0.6	Bond	0.0	0.0	0.0	0.1
Massac	0.1	0.3	0.3	0.6	Hamilton	0.0	0.0	0.0	0.0
Hardin	0.1	0.3	0.3	0.6					
Henderson	0.1	0.3	0.3	0.6	STATE B/C	0.1	0.2	0.3	0.5
LaSalle	0.1	0.3	0.3	0.6	RATIO				
Scott	0.1	0.2	0.3	0.6					
Kendall	0.1	0.2	0.3	0.6					
Fayette	0.1	0.2	0.3	0.6					
Cass	0.1	0.2	0.3	0.6					
Iroquois	0.1	0.2	0.3	0.6					
Pope	0.1	0.2	0.3	0.6					
DeWitt	0.1	0.2	0.3	0.6					
Jersey	0.1	0.2	0.3	0.5					
Lawrence	0.1	0.2	0.2	0.5					
Livingston	0.1	0.2	0.2	0.5					
Jackson	0.1	0.2	0.2	0.5					
DeKalb	0.1	0.2	0.2	0.5					
Marshall	0.1	0.2	0.2	0.5					
Piatt	0.1	0.2	0.2	0.5					
Randolph	0.1	0.2	0.2	0.5					
St. Clair	0.1	0.2	0.2	0.5					
Greene	0.1	0.2	0.2	0.4					
White	0.1	0.2	0.2	0.4					
Montgomery	0.1	0.2	0.2	0.4					
Macon	0.1	0.2	0.2	0.4					
Christian	0.1	0.2	0.2	0.4					
Woodford	0.1	0.2	0.2	0.4					
Stark	0.1	0.2	0.2	0.4					
Madison	0.1	0.2	0.2	0.4					
Williamson	0.1	0.2	0.2	0.4					
Calhoun	0.1	0.2	0.2	0.4					
Warren	0.1	0.2	0.2	0.4					
Crawford	0.1	0.2	0.2	0.4					
Clinton	0.1	0.2	0.2	0.4					
Washington	0.1	0.2	0.2	0.4					
Marion	0.1	0.2	0.2	0.4					

Appendix A continued

Table A7 Projected benefits and cost of geologic mapping program for Illinois (scenario 3).

No.	Score	County	Area	Category 1		Category 2		Category 3		Category 4	
				Estimated benefits (1900\$)	Estimated cost (1990\$)	Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)	
1	796	Winnebago	516	--	193,985	--	--	--	--	--	--
2	688	Whiteside	682	46,255	256,391	125,275	143,103	310,779	487,610	654,322	1,518,239
3	682	McHenry	606	40,750	227,820	110,365	126,071	273,791	429,575	576,446	1,337,541
4	673	Alexander	236	15,661	88,722	42,415	48,451	105,221	165,091	221,535	514,033
5	649	Mason	536	34,303	201,504	92,904	106,125	230,474	361,612	485,247	1,125,929
6	621	Ogle	759	46,489	285,338	125,907	143,825	312,346	490,069	657,622	1,525,897
7	606	Kankakee	679	40,570	255,263	109,877	125,513	272,580	427,676	573,897	1,331,626
8	605	DuPage	337	20,088	126,692	54,406	62,149	134,969	211,766	284,168	659,362
9	605	Rock Island	423	25,209	159,023	68,273	77,989	169,371	265,741	356,597	827,421
10	581	Kane	524	29,999	196,992	81,247	92,809	201,555	316,238	424,359	984,649
11	558	Cook	958	52,702	360,150	142,736	163,048	354,094	555,571	745,519	1,729,846
12	557	Stephenson	564	30,958	212,030	83,846	95,777	208,001	326,353	437,932	1,016,143
13	542	Carroll	444	23,718	166,917	64,237	73,379	159,358	250,032	335,517	778,508
14	539	Will	844	44,848	317,293	121,462	138,747	301,320	472,769	634,407	1,472,029
15	522	Monroe	388	19,983	145,865	54,120	61,821	134,258	210,650	282,671	655,887
16	518	Union	414	21,121	155,639	57,203	65,344	141,908	222,653	298,778	693,261
17	513	Mercer	559	28,268	210,150	76,558	87,453	189,922	297,987	399,868	927,822
18	510	Pulaski	203	10,212	76,316	27,657	31,592	68,610	107,648	144,453	335,177
19	502	Putnam	160	7,924	60,150	21,462	24,516	53,243	83,537	112,098	260,105
20	481	Henry	824	39,052	309,774	105,767	120,819	262,384	411,678	552,430	1,281,816
21	478	Ford	486	22,901	182,707	62,023	70,849	153,864	241,411	323,949	751,667
22	477	JoDavies	603	28,342	226,692	76,761	87,684	190,426	298,777	400,928	930,282
23	475	Lee	725	33,940	272,556	91,920	105,000	228,031	357,779	480,103	1,113,994
24	473	Tazewell	650	30,331	244,361	82,147	93,837	203,787	319,741	429,059	995,557
25	451	Bureau	869	38,622	326,692	104,601	119,487	259,492	407,141	546,342	1,267,690
26	450	Lake	454	20,152	170,677	54,579	62,346	135,398	212,438	285,070	661,454
27	424	Boone	282	--	106,015	--	--	--	--	--	--
28	415	Gallatin	325	13,287	122,180	35,985	41,106	89,271	140,066	187,954	436,113
29	409	Johnson	346	13,957	130,075	37,801	43,181	93,777	147,135	197,440	458,124
30	406	Grundy	423	16,933	159,023	45,862	52,388	113,772	178,507	239,538	555,807
31	399	Logan	619	24,362	232,707	65,980	75,369	163,681	256,814	344,617	799,624
32	397	Pike	830	32,462	312,030	87,919	100,430	218,106	342,206	459,206	1,065,507
33	387	Champaign	998	38,090	375,188	103,162	117,842	255,920	401,537	538,821	1,250,240
34	385	Massac	241	9,158	90,602	24,803	28,333	61,531	96,541	129,548	300,594
35	385	Hardin	181	6,861	68,045	18,581	21,225	46,094	72,322	97,048	225,183
36	380	Henderson	373	13,971	140,226	37,837	43,222	93,866	147,275	197,628	458,560
37	374	LaSalle	1139	42,003	428,195	113,759	129,948	282,210	442,785	594,172	1,378,672
38	371	Scott	251	9,169	94,361	24,833	28,367	61,605	96,658	129,705	300,957
39	361	Kendall	322	11,457	121,053	31,031	35,446	76,980	120,780	162,075	376,066
40	357	Fayette	709	24,954	266,541	67,585	77,203	167,662	263,061	353,001	819,076
41	351	Cass	374	12,949	140,602	35,071	40,062	87,003	136,507	183,179	425,035
42	339	Iroquois	1118	37,399	420,301	101,289	115,703	251,275	394,249	529,041	1,227,547
43	333	Pope	374	12,295	140,602	33,299	38,037	82,606	129,609	173,922	403,555
44	332	DeWitt	397	12,984	149,248	35,164	40,168	87,234	136,870	183,665	426,163
45	328	Jersey	373	12,064	140,226	32,674	37,324	81,056	127,177	170,658	395,983
46	322	Lawrence	374	11,879	140,602	32,173	36,752	79,815	125,229	168,044	389,917
47	314	Livingston	1046	32,342	393,233	87,592	100,057	217,295	340,934	457,498	1,061,544
48	289	Jackson	590	16,783	221,805	45,454	51,923	112,761	176,922	237,411	550,870
49	288	DeKalb	634	18,006	238,346	48,766	55,706	120,978	189,813	254,709	591,008
50	287	Marshall	388	10,976	145,865	29,726	33,956	73,744	115,703	155,262	360,258
51	283	Piatt	439	12,227	165,038	33,115	37,828	82,152	128,895	172,964	401,334
52	277	Randolph	583	15,905	219,173	43,075	49,205	106,859	167,662	224,985	522,037
53	275	St. Clair	672	18,201	252,632	49,294	56,309	122,287	191,867	257,466	597,404
54	269	Greene	543	14,389	204,135	38,972	44,517	96,679	151,689	203,551	472,305
55	263	White	497	12,866	186,842	34,846	39,805	86,445	135,632	182,004	422,307
56	262	Montgomery	705	18,234	265,038	49,384	56,412	122,511	192,219	257,938	598,500
57	262	Macon	581	15,006	218,421	40,641	46,424	100,821	158,187	212,271	492,537
58	261	Christian	710	18,277	266,917	49,500	56,544	122,797	192,667	258,540	599,896
59	261	Woodford	527	13,559	198,120	36,723	41,949	91,101	142,937	191,807	445,054
60	257	Stark	288	7,296	108,271	19,760	22,572	49,019	76,910	103,206	239,471
61	255	Madison	728	18,294	273,684	49,547	56,598	122,916	192,854	258,790	600,477
62	252	Williamson	427	10,598	160,526	28,702	32,787	71,204	111,718	149,915	347,851
63	248	Calhoun	250	6,111	93,985	16,552	18,907	41,061	64,424	86,451	200,594
64	241	Warren	543	12,925	204,135	35,007	39,988	86,843	136,256	182,842	424,252
65	238	Crawford	446	10,464	167,669	28,340	32,373	70,305	110,307	148,021	343,457
66	236	Clinton	472	10,980	177,444	29,737	33,969	73,772	115,747	155,321	360,395

Appendix A continued

Table A7 Continued.

No.	Score	County	Area	Category 1,		Category 2		Category 3		Category 4	
				Estimated benefits (1900\$)	Estimated cost (1990\$)	Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)		Range of estimated benefits (1990\$)	
67	227	Washington	563	12,622	211,654	34,186	39,050	84,806	133,061	178,554	414,302
68	225	Marion	573	12,712	215,414	34,429	39,328	85,409	134,007	179,823	417,248
69	221	Menard	315	6,859	118,421	18,576	21,220	46,083	72,304	97,024	225,127
70	215	Peoria	621	13,191	233,459	35,724	40,808	88,624	139,050	186,591	432,952
71	211	Hancock	796	16,581	299,248	44,908	51,298	111,405	174,794	234,555	544,245
72	205	McLean	1185	23,906	445,489	64,746	73,960	160,621	252,013	338,176	784,678
73	195	Adams	852	16,360	320,301	44,309	50,615	109,920	172,464	231,430	536,991
74	189	Wabash	224	4,173	84,211	11,302	12,911	28,039	43,993	59,034	136,977
75	183	Vermilion	900	16,264	338,346	44,049	50,318	109,276	171,453	230,073	533,843
76	179	Clay	469	8,296	176,316	22,469	25,666	55,740	87,455	117,356	272,303
77	172	Knox	720	12,217	270,677	33,086	37,795	82,080	128,783	172,813	400,982
78	166	Perry	443	7,230	166,541	19,581	22,368	48,577	76,217	102,276	237,312
79	164	Franklin	414	6,711	155,639	18,176	20,762	45,090	70,746	94,934	220,277
80	162	Moultrie	325	5,197	122,180	14,074	16,077	34,915	54,781	73,510	170,567
81	159	Edgar	623	9,743	234,211	26,387	30,142	65,460	102,706	137,820	319,788
82	155	Clark	506	7,732	190,226	20,941	23,921	51,950	81,509	109,376	253,788
83	155	Saline	385	5,871	144,737	15,900	18,163	39,445	61,889	83,049	192,701
84	148	Jefferson	570	8,299	214,286	22,477	25,676	55,761	87,488	117,400	272,406
85	142	Wayne	715	10,011	268,797	27,113	30,971	67,260	105,531	141,612	328,585
86	141	Brown	306	4,260	115,038	11,537	13,179	28,621	44,907	60,260	139,823
87	138	Jasper	496	6,757	186,466	18,301	20,905	45,401	71,233	95,588	221,795
88	137	Douglas	417	5,651	156,767	15,304	17,482	37,965	59,567	79,933	185,470
89	136	Fulton	871	11,716	327,444	31,731	36,246	78,716	123,505	165,731	384,550
90	136	Coles	509	6,813	191,353	18,452	21,078	45,775	71,820	96,375	223,622
91	133	Sangamon	866	11,315	325,564	30,644	35,005	76,022	119,277	160,058	371,386
92	132	Schuyler	436	5,694	163,910	15,421	17,616	38,257	60,025	80,547	186,895
93	119	Morgan	568	6,653	213,534	18,017	20,581	44,697	70,128	94,105	218,355
94	111	Richland	360	3,946	135,338	10,686	12,207	26,510	41,593	55,814	129,506
95	110	Effingham	478	5,199	179,699	14,080	16,084	34,930	54,804	73,542	170,641
96	109	Shelby	747	8,002	280,827	21,671	24,755	53,760	84,350	113,189	262,634
97	109	Cumberland	346	3,703	130,075	10,028	11,456	24,878	39,034	52,379	121,537
98	83	McDonough	590	4,826	221,805	13,070	14,929	32,422	50,871	68,263	158,392
99	82	Edwards	223	1,796	83,835	4,863	5,555	12,064	18,928	25,400	58,936
100	67	Macoupin	865	5,705	325,188	15,450	17,649	38,328	60,136	80,696	187,242
101	61	Bond	377	2,263	141,729	6,128	7,000	15,202	23,851	32,006	74,264
102	18	Hamilton	436	793	163,910	2,147	2,452	5,325	8,355	11,211	26,014
TOTALS				\$1,797,139	\$20,921,429	\$4,867,252	\$5,559,899	\$12,074,528	\$18,944,841	\$25,422,030	\$58,987,347

Appendix A continued

Table A8 Projected B/C ratios by county (scenario 3, lower cost base).

County	Category 1	Category 2 range	Category 3 range	Category 4 range	County	Category 1	Category 2 range	Category 3 range	Category 4 range
Winnebago	--	--	--	--	Menard	0.1	0.2	0.2	0.4 0.6 0.8 1.9
Whiteside	0.2	0.5	0.6	1.2 1.9 2.6 5.9	Peoria	0.1	0.2	0.2	0.4 0.6 0.8 1.9
McHenry	0.2	0.5	0.6	1.2 1.9 2.5 5.9	Hancock	0.1	0.2	0.2	0.4 0.6 0.8 1.8
Alexander	0.2	0.5	0.5	1.2 1.9 2.5 5.8	McLean	0.1	0.1	0.2	0.4 0.6 0.8 1.8
Mason	0.2	0.5	0.5	1.1 1.8 2.4 5.6	Adams	0.1	0.1	0.2	0.3 0.5 0.7 1.7
Ogle	0.2	0.4	0.5	1.1 1.7 2.3 5.3	Wabash	0.0	0.1	0.2	0.3 0.5 0.7 1.6
Kankakee	0.2	0.4	0.5	1.1 1.7 2.2 5.2	Vermilion	0.0	0.1	0.1	0.3 0.5 0.7 1.6
DuPage	0.2	0.4	0.5	1.1 1.7 2.2 5.2	Clay	0.0	0.1	0.1	0.3 0.5 0.7 1.5
Rock Island	0.2	0.4	0.5	1.1 1.7 2.2 5.2	Knox	0.0	0.1	0.1	0.3 0.5 0.6 1.5
Kane	0.2	0.4	0.5	1.0 1.6 2.2 5.0	Perry	0.0	0.1	0.1	0.3 0.5 0.6 1.4
Cook	0.1	0.4	0.5	1.0 1.5 2.1 4.8	Franklin	0.0	0.1	0.1	0.3 0.5 0.6 1.4
Stephenson	0.1	0.4	0.5	1.0 1.5 2.1 4.8	Moultrie	0.0	0.1	0.1	0.3 0.4 0.6 1.4
Carroll	0.1	0.4	0.4	1.0 1.5 2.0 4.7	Edgar	0.0	0.1	0.1	0.3 0.4 0.6 1.4
Will	0.1	0.4	0.4	0.9 1.5 2.0 4.6	Clark	0.0	0.1	0.1	0.3 0.4 0.6 1.3
Monroe	0.1	0.4	0.4	0.9 1.4 1.9 4.5	Saline	0.0	0.1	0.1	0.3 0.4 0.6 1.3
Union	0.1	0.4	0.4	0.9 1.4 1.9 4.5	Jefferson	0.0	0.1	0.1	0.3 0.4 0.5 1.3
Mercer	0.1	0.4	0.4	0.9 1.4 1.9 4.4	Wayne	0.0	0.1	0.1	0.3 0.4 0.5 1.2
Pulaski	0.1	0.4	0.4	0.9 1.4 1.9 4.4	Brown	0.0	0.1	0.1	0.2 0.4 0.5 1.2
Putnam	0.1	0.4	0.4	0.9 1.4 1.9 4.3	Jasper	0.0	0.1	0.1	0.2 0.4 0.5 1.2
Henry	0.1	0.3	0.4	0.8 1.3 1.8 4.1	Oouglas	0.0	0.1	0.1	0.2 0.4 0.5 1.2
Ford	0.1	0.3	0.4	0.8 1.3 1.8 4.1	Fulton	0.0	0.1	0.1	0.2 0.4 0.5 1.2
JoDaviess	0.1	0.3	0.4	0.8 1.3 1.8 4.1	Coles	0.0	0.1	0.1	0.2 0.4 0.5 1.2
Lee	0.1	0.3	0.4	0.8 1.3 1.8 4.1	Sangamon	0.0	0.1	0.1	0.2 0.4 0.5 1.1
Tazewell	0.1	0.3	0.4	0.8 1.3 1.8 4.1	Schuyler	0.0	0.1	0.1	0.2 0.4 0.5 1.1
Bureau	0.1	0.3	0.4	0.8 1.2 1.7 3.9	Morgan	0.0	0.1	0.1	0.2 0.3 0.4 1.0
Lake	0.1	0.3	0.4	0.8 1.2 1.7 3.9	Richland	0.0	0.1	0.1	0.2 0.3 0.4 1.0
Boone	--	--	--	--	Effingham	0.0	0.1	0.1	0.2 0.3 0.4 0.9
Gallatin	0.1	0.3	0.3	0.7 1.1 1.5 3.6	Shelby	0.0	0.1	0.1	0.2 0.3 0.4 0.9
Johnson	0.1	0.3	0.3	0.7 1.1 1.5 3.5	Cumberland	0.0	0.1	0.1	0.2 0.3 0.4 0.9
Grundy	0.1	0.3	0.3	0.7 1.1 1.5 3.5	McDonough	0.0	0.1	0.1	0.1 0.2 0.3 0.7
Logan	0.1	0.3	0.3	0.7 1.1 1.5 3.4	Edwards	0.0	0.1	0.1	0.1 0.2 0.3 0.7
Pike	0.1	0.3	0.3	0.7 1.1 1.5 3.4	Macoupin	0.0	0.0	0.1	0.1 0.2 0.2 0.6
Champaign	0.1	0.3	0.3	0.7 1.1 1.4 3.3	Bond	0.0	0.0	0.0	0.1 0.2 0.2 0.5
Massac	0.1	0.3	0.3	0.7 1.1 1.4 3.3	Hamilton	0.0	0.0	0.0	0.0 0.1 0.1 0.2
Hardin	0.1	0.3	0.3	0.7 1.1 1.4 3.3					
Henderson	0.1	0.3	0.3	0.7 1.1 1.4 3.3	STATE B/C	0.1	0.2	0.3	0.6 0.9 1.2 2.8
LaSalle	0.1	0.3	0.3	0.7 1.0 1.4 3.2	RATIO				
Scott	0.1	0.3	0.3	0.7 1.0 1.4 3.2					
Kendall	0.1	0.3	0.3	0.6 1.0 1.3 3.1					
Fayette	0.1	0.3	0.3	0.6 1.0 1.3 3.1					
Cass	0.1	0.2	0.3	0.6 1.0 1.3 3.0					
Iroquois	0.1	0.2	0.3	0.6 0.9 1.3 2.9					
Pope	0.1	0.2	0.3	0.6 0.9 1.2 2.9					
DeWitt	0.1	0.2	0.3	0.6 0.9 1.2 2.9					
Jersey	0.1	0.2	0.3	0.6 0.9 1.2 2.8					
Lawrence	0.1	0.2	0.3	0.6 0.9 1.2 2.8					
Livingston	0.1	0.2	0.3	0.6 0.9 1.2 2.7					
Jackson	0.1	0.2	0.2	0.5 0.8 1.1 2.5					
DeKalb	0.1	0.2	0.2	0.5 0.8 1.1 2.5					
Marshall	0.1	0.2	0.2	0.5 0.8 1.1 2.5					
Piatt	0.1	0.2	0.2	0.5 0.8 1.0 2.4					
Randolph	0.1	0.2	0.2	0.5 0.8 1.0 2.4					
St. Clair	0.1	0.2	0.2	0.5 0.8 1.0 2.4					
Greene	0.1	0.2	0.2	0.5 0.7 1.0 2.3					
White	0.1	0.2	0.2	0.5 0.7 1.0 2.3					
Montgomery	0.1	0.2	0.2	0.5 0.7 1.0 2.3					
Macon	0.1	0.2	0.2	0.5 0.7 1.0 2.3					
Christian	0.1	0.2	0.2	0.5 0.7 1.0 2.2					
Woodford	0.1	0.2	0.2	0.5 0.7 1.0 2.2					
Stark	0.1	0.2	0.2	0.5 0.7 1.0 2.2					
Madison	0.1	0.2	0.2	0.4 0.7 0.9 2.2					
Williamson	0.1	0.2	0.2	0.4 0.7 0.9 2.2					
Calhoun	0.1	0.2	0.2	0.4 0.7 0.9 2.1					
Warren	0.1	0.2	0.2	0.4 0.7 0.9 2.1					
Crawford	0.1	0.2	0.2	0.4 0.7 0.9 2.0					
Clinton	0.1	0.2	0.2	0.4 0.7 0.9 2.0					
Washington	0.1	0.2	0.2	0.4 0.6 0.8 2.0					
Marion	0.1	0.2	0.2	0.4 0.6 0.8 1.9					

Appendix A continued

Table A9 Projected B/C ratios by county (scenario 3, higher cost base).

County	Category 1	Category 2 range	Category 3 range	Category 4 range	County	Category 1	Category 2 range	Category 3 range	Category 4 range
Winnebago	--	--	--	--	Menard	0.0	0.1	0.1	0.1
Whiteside	0.1	0.2	0.2	0.5	Peoria	0.0	0.1	0.1	0.1
McHenry	0.1	0.2	0.2	0.5	Hancock	0.0	0.1	0.1	0.1
Alexander	0.1	0.2	0.2	0.5	McLean	0.0	0.1	0.1	0.1
Mason	0.1	0.2	0.2	0.4	Adams	0.0	0.1	0.1	0.1
Ogle	0.1	0.2	0.2	0.4	Wabash	0.0	0.1	0.1	0.1
Kankakee	0.1	0.2	0.2	0.4	Vermilion	0.0	0.0	0.1	0.1
DuPage	0.1	0.2	0.2	0.4	Clay	0.0	0.0	0.1	0.1
Rock Island	0.1	0.2	0.2	0.4	Knox	0.0	0.0	0.1	0.1
Kane	0.1	0.2	0.2	0.4	Perry	0.0	0.0	0.1	0.1
Cook	0.1	0.2	0.2	0.4	Franklin	0.0	0.0	0.1	0.1
Stephenson	0.1	0.2	0.2	0.4	Moultrie	0.0	0.0	0.0	0.1
Carroll	0.1	0.1	0.2	0.4	Edgar	0.0	0.0	0.0	0.1
Will	0.1	0.1	0.2	0.4	Clark	0.0	0.0	0.0	0.1
Monroe	0.1	0.1	0.2	0.3	Saline	0.0	0.0	0.0	0.1
Union	0.1	0.1	0.2	0.3	Jefferson	0.0	0.0	0.0	0.1
Mercer	0.1	0.1	0.2	0.3	Wayne	0.0	0.0	0.0	0.1
Pulaski	0.1	0.1	0.2	0.3	Brown	0.0	0.0	0.0	0.1
Putnam	0.1	0.1	0.2	0.3	Jasper	0.0	0.0	0.0	0.1
Henry	0.0	0.1	0.1	0.3	Douglas	0.0	0.0	0.0	0.1
Ford	0.0	0.1	0.1	0.3	Fulton	0.0	0.0	0.0	0.1
JoDavies	0.0	0.1	0.1	0.3	Coles	0.0	0.0	0.0	0.1
Lee	0.0	0.1	0.1	0.3	Sangamon	0.0	0.0	0.0	0.1
Tazewell	0.0	0.1	0.1	0.3	Schuyler	0.0	0.0	0.0	0.1
Bureau	0.0	0.1	0.1	0.3	Morgan	0.0	0.0	0.0	0.1
Lake	0.0	0.1	0.1	0.3	Richland	0.0	0.0	0.0	0.1
Boone	--	--	--	--	Effingham	0.0	0.0	0.0	0.1
Gallatin	0.0	0.1	0.1	0.3	Shelby	0.0	0.0	0.0	0.1
Johnson	0.0	0.1	0.1	0.3	Cumberland	0.0	0.0	0.0	0.1
Grundy	0.0	0.1	0.1	0.3	McDonough	0.0	0.0	0.0	0.1
Logan	0.0	0.1	0.1	0.3	Edwards	0.0	0.0	0.0	0.1
Pike	0.0	0.1	0.1	0.3	Macoupin	0.0	0.0	0.0	0.1
Champaign	0.0	0.1	0.1	0.3	Bond	0.0	0.0	0.0	0.1
Massac	0.0	0.1	0.1	0.3	Hamilton	0.0	0.0	0.0	0.1
Hardin	0.0	0.1	0.1	0.3					
Henderson	0.0	0.1	0.1	0.3	STATE B/C	0	0.1	0.1	0.2
LaSalle	0.0	0.1	0.1	0.3	RATIO				
Scott	0.0	0.1	0.1	0.2					
Kendall	0.0	0.1	0.1	0.2					
Fayette	0.0	0.1	0.1	0.2					
Cass	0.0	0.1	0.1	0.2					
Iroquois	0.0	0.1	0.1	0.2					
Pope	0.0	0.1	0.1	0.2					
DeWitt	0.0	0.1	0.1	0.2					
Jersey	0.0	0.1	0.1	0.2					
Lawrence	0.0	0.1	0.1	0.2					
Livingston	0.0	0.1	0.1	0.2					
Jackson	0.0	0.1	0.1	0.2					
DeKalb	0.0	0.1	0.1	0.2					
Marshall	0.0	0.1	0.1	0.2					
Piatt	0.0	0.1	0.1	0.2					
Randolph	0.0	0.1	0.1	0.2					
St. Clair	0.0	0.1	0.1	0.2					
Greene	0.0	0.1	0.1	0.2					
White	0.0	0.1	0.1	0.2					
Montgomery	0.0	0.1	0.1	0.2					
Macon	0.0	0.1	0.1	0.2					
Christian	0.0	0.1	0.1	0.2					
Woodford	0.0	0.1	0.1	0.2					
Stark	0.0	0.1	0.1	0.2					
Madison	0.0	0.1	0.1	0.2					
Williamson	0.0	0.1	0.1	0.2					
Calhoun	0.0	0.1	0.1	0.2					
Warren	0.0	0.1	0.1	0.2					
Crawford	0.0	0.1	0.1	0.2					
Clinton	0.0	0.1	0.1	0.2					
Washington	0.0	0.1	0.1	0.2					
Marion	0.0	0.1	0.1	0.2					

APPENDIX B

RESPONSES TO QUESTIONNAIRE: USE OF, REQUIREMENTS FOR, AND PRIORITIES FOR GEOLOGIC MAPS IN ILLINOIS

This is a summary of responses to a questionnaire (Damberger 1990) mailed in spring 1990 to members of the Illinois Geologic Mapping Advisory Committee (IGMAC) and some other known users of geologic maps.

Response Rate

Of the 80 questionnaires distributed, 36 were returned. Four recipients called to say that they were not in a position to respond because they had not used or produced geologic maps for some time. Thus, the response rate was about 50 percent, generally considered a good response rate to mailed questionnaires.

Background of respondents	No.
Federal and state research and service agencies	11
Planning/development agencies/departments	7
Consulting engineers/geologists	7
State or federal environmental or health agencies	6
Mineral extraction industry	3
Universities	2
Total	36

The 36 respondents listed uses of geologic maps and data. More than one use could be listed.

1 Use of geologic data/maps

Siting		Resource development and exploration		Planning/environmental protection	
Waste disposal	11	Soil	9	Groundwater	13
Hydrologic projects	11	Water	9	Geologic hazards	10
Industry projects	10	Sand and gravel	4	Land use	9
Transportation	7	Lead, zinc, fluorspar	4	Mineral protection	2
Commercial projects	6	Stone	9	Other	2
Residential projects	2	Coal	2		
Other	8	Oil and gas	2		
		Other	4		
Total	55	Total	43	Total	36

2 Specific geologic information required

Location on mines, quarries, etc.	16	Thickness of strata	11
Character of earth materials to bedrock	14	Character of bedrock surface	11
Regional structure	7	Depth to bedrock	14
Outcrop of coal seams	3	Character of earth materials at surface	13
Other	4	Location of faults	12

3 Map products used in recent 2-year period

Topographic maps	7	Aerial photos	1
Quaternary maps	6	Atlas/state maps	1
ISGS/USGS geological maps	7	DLG file	1
ISGS potential contamination maps	2	Plot books	1
Zoning maps	1	Wetlands map	2
Highway maps	1	Rail maps	1

Appendix B continued

4 Projects identified requiring geologic maps

General

- Highway soil surveys
- Foundation investigations
- Aggregate exploration projects
- Numerous construction projects
- Determination of setback zones around public water supplies (PWS) well heads
- Groundwater hazard reviews for PWS
- Permitting PWS wells after effective date of Illinois Groundwater Protection Act
- Numerous USEPA preremedial sites in Illinois
- Environmental assessment projects
- Hazardous waste investigations
- Geotechnical engineering reports
- Foundation investigations for buildings, dams, levees, bridges

Specific projects

- Superconducting Super Collider (SSC)
- Core drilling project in fluorspar mining district of southeast Illinois
- Winnebago County groundwater study
- Available coal resources of Middletown quad, Logan County
- Coal resources of Paducah 1°×2° Quadrangle (CUSMAP), southern Illinois
- Compilation of noncoal mines of Illinois
- Correlation of stratigraphic data for National Coal Resources Data System (NCRDS)
- IEPA Remedial Investigations and Feasibility Studies in Rockdale
- Solid Waste Agency of Northern Cook County (SWANCC), balefill, Cook County
- CUP-O'Hare Reservoir, Cook County
- Wooddale-Itasca Reservoir, Du Page County
- Investigation of hazardous chemical dump northwest of Rockford, Illinois
- Winnebago County
- Water well methane explosion in Kane County
- Petroleum releases in Winnebago and Warren Counties
- Air storage reservoir exploration in La Salle County

- Highway soil surveys
- Quarry appraisals in Will County
- Feasibility of injection of industrial wastes in deep wells, Illinois
- Groundwater monitoring projects
- Watershed analyses in many counties
- Numerous purchases and exchanges of land, Shawnee National Forest
- Capital improvement projects, city of Chicago
- Paleobotanical research, western Illinois
- Study till and loess stratigraphy, southwest Illinois
- Develop contamination potential maps
- Develop groundwater quality trend maps
- Land use versus rainfall runoff, modeling studies

- Site assessment and environmental audit in Du Page County
- Remedial assessment of groundwater contamination, Champaign County
- Develop regional groundwater monitoring program, Cook County
- Regional groundwater quality characterization, Winnebago County
- Landfill siting, Kane County
- Siting municipal wells, Kane County
- Develop land use plan, Kane County
- Siting of coal gasification plant
- Develop land management plan for Shawnee National Forest
- Groundwater contamination assessments in Boone, Winnebago, Kendall, and McLean Counties
- Hydrologic budget study, Joliet Army Ammunition Plant
- Archeological site investigation, McLean County
- Study of archeology of state parks, Illinois
- Sites for low-level nuclear waste facility, Clark and Wayne Counties

5 Importance of geological maps in these projects

Useful	13
Critical	12
Not needed	0

6 Order of priority by area*

Region	Avg priority	No.	Urban area	Avg priority	No.	Urban area	Avg priority	No.
Northeast	1.0	8	Chicago	1.2	5	Rockford	4.0	1
Southwest	2.3	9	Chicago suburbs	1.6	6	Aurora	3.0	1
Southeast	3.0	8	Quad cities	3.0	3	Bloomington	4.0	1
Central	3.0	5	Springfield	4.0	3	Kankakee	6.0	1
East central	3.2	4	Joliet	4.0	2	Elgin	11.0	1
West central	3.3	6	Peoria	5.0	2	Galesburg	14.0	1
Northwest	3.7	4	Decatur	7.5	2	Champaign	15.0	1
			Danville	7.5	2			

*Avg priority, average given to these areas by respondents who provided priorities (many respondents did not prioritize). No., number of times mentioned by respondents.

Appendix B *continued*

6 Order of priority by area *continued*

County	Avg priority	No.	Other counties mentioned more than once	
Cook	1.0	4	Adams	Lee
Du Page	2.0	4	Alexander	Macon
Lake	2.3	4	Bond	Macoupon
Rock Island	6.0	4	Boone	Menard
Will	7.0	4	Bureau	Mercer
De Kalb	4.0	3	Calhoun	Moultrie
Jo Daviess	8.0	3	Cass	Piatt
Tazewell	12.0	3	Champaign	Pike
Peoria	16.0	3	Christian	Pope
Ogle	20.0	3	Clinton	Putnam
Sangamon	1.0	2	De Witt	St. Clair
McLean	3.0	2	Franklin	Saline
Kane	5.0	2	Gallatin	Shelby
Kendall	6.0	2	Green	Stephenson
Logan	7.0	2	Grundy	Union
McHenry	7.0	2	Henderson	Warren
Brown	11.0	2	Jasper	Whiteside
Schuyler	11.0	2	Jefferson	Winnebago
Hancock	12.0	2	Johnson	Woodford
McDonough	12.0	2	La Salle	
Jersey	12.0	2		
Madison	13.0	2		
Henry	15.0	2		
Kankakee	17.0	2		

7 Map scales needed

Scale	Avg priority	No.	Scale	Avg priority	No.
1:24,000	1.4	15	1:250,000	2.7	4
1:50,000	2.2	6	Other	1	
1:100,000	1.5	6	1:500,000	3.7	5

8a Cost/year of lack of adequate geologic maps*

<\$5,000	7	\$100,000 to \$1,000,000	4	>\$1,000,000	1(?)
\$10,000 to \$100,000	5	\$5,000 to \$10,000	2	Unknown	17

*Cumulative extra cost per year estimated by 19 respondents answering this question is \$1.5 to \$5.5 million.

8b Savings from availability of adequate geologic maps*

\$10,000 to \$100,000	6	<\$5,000	2	\$100,000 to \$1,000,000	1
\$5,000 to \$10,000	3	>\$1,000,000	2	Unknown or no answer	22

*Cumulative savings per year estimated by 14 respondents answering question is \$2.2 to \$3.6 million.

9 Number of people using geologic maps in organization of respondents*

11 to 50	10	6 to 10	6	No answer	8
<5	8	>50	4		

*Estimated number of regular users of geologic maps by 28 respondents answering questions is 390 to 800.

Appendix B continued

10 Sources of geologic information in work*

	Avg rank	No.		Avg rank	No.
Basic geologic maps	1.9	20	Publications	2.5	19
Drilling records	3.0	13	Interpretive/derivative maps	3.3	7
Own geologic database	3.8	10	Unpublished data at ISGS	5.1	11
Consultants	5.8	7	Field mapping	5.9	7
Unpublished data at university geology departments	7.5	4	Unpublished data at USGS	7.0	6
			Other		2

*Avg rank, average of all answers that provided rank. No., number of times mentioned.

11 Degree of satisfaction with currently available geologic maps

	Geologic maps			Geologic data					
				Paper			Electronic		
	A	B	C	A	B	C	A	B	C
Type of data	6	9	2	5	8	1	2	2	3
Format of data	7	10	0	4	6	2	2	2	1
Accuracy of data	8	6	3	6	5	3	1	3	2
Level of detail	4	9	4	5	5	4	1	3	3
Areal coverage	3	9	5	1	9	4	1	3	2

*A, satisfied; B, neutral; C, dissatisfied. Numbers are responses in each category.

12 Identification of projects that suffered due to a lack of geologic maps or benefited from available geologic maps

No answers provided

13 Additional geologic maps that were mentioned

- Bedrock surface maps of Chicago area (± 5 -foot contours) (mentioned 2 times)
- Quaternary map 1:1,000,000 scale or larger, joined accurately with neighboring states, including digital file (mentioned 2 times)
- Till sheet extent, including engineering properties
- Possible targets for future fluorspar, zinc, and lead exploration
- Protection of natural resources in northeast Illinois is critical now (requiring adequate geologic maps); will include entire state in future
- Geologic maps needed to establish well head protection (setback zones, regulate recharge areas, groundwater protection needs assessment, hazard reviews)
- Large-scale geologic maps of glacial surface deposits, glacial thickness, glacial till member isopachs, bedrock surface topography, bedrock surface geology, bedrock structure, potentiometric maps of major aquifers
- Sand and gravel isopach maps, for groundwater assessments
- Large-scale geologic maps of Kane County to help in protection of shallow aquifers
- More detailed maps showing subsurficial features in developed areas, especially relative to groundwater
- Maps helping in assessment of hazards resulting from major earthquake along New Madrid fault zone
- Maps of aquifers, groundwater flow patterns, particularly in densely populated and industrialized areas
- Geologic maps in digital form are needed (mentioned several times)
- County geologic maps for SCS field offices
- More complete coverage by geologic maps of Alexander, Jackson, Johnson, and Union Counties needed by Shawnee National Forest administration
- Areas of state with greatest susceptibility to groundwater contamination need to be mapped thoroughly
- Till sheet (near surface) extent (differentiated by engineering properties) in northeast Illinois
- Reef locations, near bedrock surface, in northeast Illinois (mentioned 2 times)
- 1:24,000- or 1:12,000-scale hydrostratigraphic maps
- Large-scale geologic mapping needed; update old maps and automate (digitize) maps
- 1:24,000 surficial geology, surficial materials, and aquifers, all down to bedrock

Appendix B *continued*

14 Laws, regulations, and ordinances that require use of geologic maps

Chicago building code

Illinois Department of Transportation (IDOT) regulations

National Environmental Protection Act (NEPA)

Resources Conservation and Recovery Act (RCRA)

APPENDIX C

SITES IN BOONE AND WINNEBAGO COUNTIES FOR WHICH QUANTIFIABLE COST ESTIMATES ARE AVAILABLE

BOONE COUNTY SUPERFUND SITES

Belvidere Municipal No. 1

\$149,307 IEPA

\$5 to \$7 million for remedial action

Assumed over a 10-year period

Bonus (Mig)

\$45,651 IEPA

\$22,000 for management assistance

\$45 million cleanup cost estimate

Parson's Outside (Parson's Casket)

\$413,487 IEPA

\$1.2 million RIFS

Pump and treat, strip, or no action as alternatives:

- Pump and treat \$2 to \$3 million for 25 to 30 years
- Operation and maintenance \$10,000 per year for 30 years

BOONE COUNTY VOLUNTARY CLEANUP SITES

Midwest Plating, Herbert

\$1,461 IEPA

WINNEBAGO COUNTY SUPERFUND SITES

Pagel's Pit (Winnebago Reclamation Service)

\$1 million RIFS

\$7,414 IEPA (as of June 30, 1990)

\$1 million cost of planning

Acme Solvents

\$1 million RIFS (1984)

\$15 to \$17 million future cleanup

\$10 million, by other responsible parties

\$59,025 IEPA

Beloit Corporation

\$14,659 IEPA

\$20,000 management assistance and federal funds

Only solvents found, treatment minimal remediation

Six Oaks in Pecatonica (Trailer Park)

\$37,000/year maintenance cost

30 years assumed

\$810,506 IEPA

IPC (Interstate Pollution Control)

(Roto Rooter)

\$10,315 IEPA (1983-84)

\$0.75 to \$1.0 million RIFS

\$100,000 IEPA oversight

\$1 million soil cleanup

Several million \$ for pump-and-treat remedy

Southeast Rockford

\$400,000 RIFS

Alternatives:

- Water line extension, \$3.3 to \$4.3 million
- Two new deep municipal wells, \$8 to \$9 million
- New private wells for everybody (250 to 300), \$8.6 to \$10.6 million
- Treat contaminated well, \$3.5 to \$5.5 million
- Treat each private well, \$30 million

Supplied water in bottles for about 2 years

\$250,000 for carbon filters for households (no state dollars spent)

WINNEBAGO COUNTY VOLUNTARY CLEANUP SITES

Warner Brake, delisted site

\$4,197 IEPA

\$1 million for well and waterline

\$3 to \$10 million treatment system, spent by company

\$39 million lawsuit by Attorney General (settled out of court)

Company agreed to cleanup

Mattison Machine Works, Rockford

Just in initial stages, \$46 state

Sunstrand Corp. will take lease

Borg-Warner Corp., Rockford

Well contamination

Borg-Warner installed well nest, \$3,000 each

\$14,447 IEPA

Sunstrand

\$5,894 IEPA

Alloy Plating, Rockford

\$20,590 IEPA

Ipsen CHT

\$23,364 IEPA

Kaney Transportation, Rockford

\$1,351 IEPA

\$100,000 for study

Illinois Water Treatment, Rockford

Sampling, \$50,000

\$2,288 IEPA

Appendix C *continued*

Woodward Governor Co., Loves Park

Tank leak, putting in a stripper tower, \$100,000 to \$200,000

Total \$200,000 to \$350,000 including monitoring well and consultant

OTHER SITES

American Brass

Waste site caused 10 to 12 houses to abandon wells and hook up to city water supply
\$2,500 to \$5,000 per hookup

People's Avenue (Quaker Oats)

No action
\$500,000 RIFS
\$2,846 IEPA

Frink's Industrial Waste (SRAPL)

\$893,143 IEPA

Hydroline

\$27 IEPA

IEPA, Summary of Boone-Winnebago

\$2,478,018, IEPA expenditures as of June 30, 1990; includes labor costs, contractual (laboratory, consultant, etc.)

Hononega Country Estates

\$27,000 in 1982 for a nitrate study

Sand Park (SRAPL)

\$2 million before remedies are designed

Oak Crest Subdivision

\$1.6 million to construct sewer lines

